▪ Determine environmental flow requirements at key locations

1.1 Reach 1: Bostock Reservoir downstream to the confluence with the west Moorabool River

The East Moorabool River downstream of Bostock Reservoir flows through the East Moorabool gorge before reaching a narrow floodplain downstream of Egerton Bungeeltap Road. Further downstream towards Egerton Bungeeltap Road, where no flow was observed, the floodplain widens and ecological condition of the riparian and instream vegetation worsens.

1.1.1 Site description

The site surveyed within this reach was immediately upstream of the narrow floodplain at Egerton Bungeltap Road. Here the river runs through a straight channel, which is bordered by a steep hillslope to the left and an eroded steep bench to the right. The channel is controlled by bedrock in the deeper pools and separated by vegetation in the shallow areas (Figure 0-1). The substrate consisted of cobbles, pebbles and sands. Stock access is particularly evident on the right bank and has probably exacerbated bank erosion.

Riparian vegetation is scattered along the edge of the river and not more than one tree wide, consisting of Woolly Tea-tree, Blackwood and bottlebrush (*Callistemon sp.*). A stand of eucalypts was present on the top of the left hillslope. Blackberries were present along the right bank at transect five. Exotic pasture grasses have replaced native species on the bench.

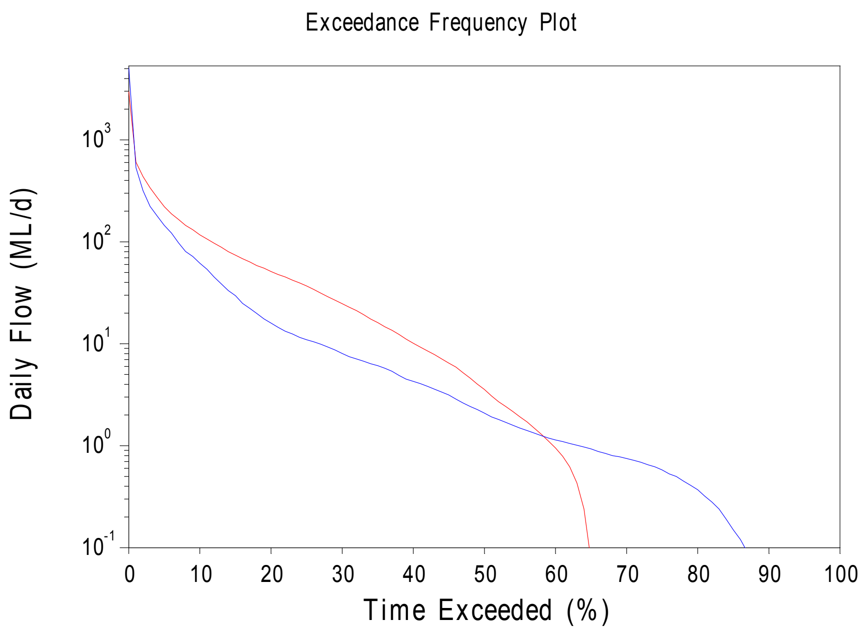
Instream vegetation was dominated by Cumbungi in the shallow areas, which often impeded flow. The pools contained Watermilfoil (*Myriophyllum sp.*), Ribbonweed (*Vallisneria sp.*) and a small amount of rush (*Juncus sp*) (Figure 0-2).

- **Figure 0-1: East Moorabool River at Egerton Bungeeltap Road, Transect 1, looking downstream (March 2003).**

- **Figure 0-2 East Moorabool River at Egerton Bungeeltap Road, Transect 2, looking downstream (March 2003).**

1.1.2 Hydrology

The flow duration curve shows that zero flows are naturally common within this reach (Figure 0-3). Currently, the flow is low and more constant. This has lead to the establishment of instream vegetation species common to more stable waters that can potentially choke the channel and impede flow.



- **Figure 0-3 East Moorabool River daily flow duration for all months. Dashed red line – natural, solid blue line – current.**

1.1.3 Environmental values

A significant knowledge gap exists for the current biological condition of the East Moorabool River. One fish survey, undertaken by Tunbridge (1988), indicates that Short-finned Eel is the only native species present. Other native species that could be potentially present within this reach and found further downstream near the confluence of the east and west branches at Morrisons include River Blackfish, Southern Pygmy Perch and Australian Smelt. However, at present, conditions would be poor habitat for these fish species as there are few pools and those that exist would have low dissolved oxygen concentrations and high temperatures. Therefore if these species were found here, their abundance would be low. The exotic species present within this reach are Redfin (*Perca fluviatilis*) and Brown Trout.

A Waterwatch site is located downstream of the bridge on Bungeeltap Road, however no macroinvertebrate monitoring is undertaken (Michelle Anderson, Barwon Water *pers. comm.*).

The East Moorabool Gorge, immediately downstream of Bostock Reservoir is known to contain significant areas of remnant grasslands (CCMA, 2000b).

1.1.4 Water quality

Water quality data was obtained from Barwon Water for the Bostock Reservoir outlet. A summary of water quality data at this site and comparison to the draft SEPP objectives is provided in **Error! Reference source not found.**.

Total phosphorus concentrations have exceeded the SEPP objective of ≤ 0.04 mg/L six of the seven years monitored since 1996. Electrical conductivity complied with four of the six years monitored, a 75th percentile maximum of 617 µS/cm in 2000. pH complied with all draft SEPP objectives and turbidity ranged from a low 75% percentile of 5.7 NTU to a maximum of 17.3 NTU in 2002.

During the site visit, high turbidity was observed in the deeper pools and where the river widened downstream of Egerton Bungeeltap Road. White scum was also visible on the surface indicating low flushing flow.

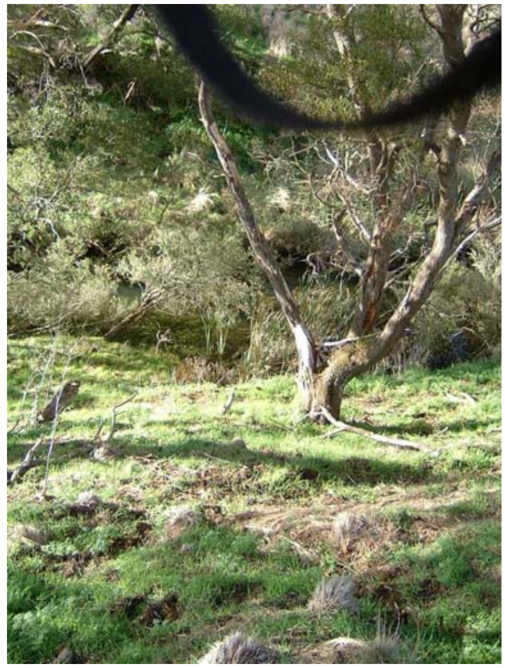
1.1.5 Issues

The natural flow regime has been significantly altered within this reach due to the impoundment of water at Bostock Reservoir. Compared to natural, there has been a decrease in cease to flow events (from 35% to 15%), median flows (3.57 to 2.09 ML/d) and an extended low flow period. The absence of these natural mechanisms has created conditions more favourable to instream vegetation species, such as Cumbungi, which are common to slow flowing shallow waters (Figure 0-4). Low median flows decrease the amount of habitat available to native fauna leading to an increase in predation and competition.

Isolation of native migratory fish species, with the probable exception of Short-finned Eels, occurs within this reach due to the presence of barriers upstream (Bostock) and downstream (She Oaks Weir).

In addition, extensive clearing of the riparian zone combined with stock access has resulted in the dominance of exotic terrestrial species such as pasture grasses (Figure 0-5).

▪ **Figure 0-4 East Moorabool River at Egerton Bungeeltap Road, Transect 2 cross section.**



▪ **Figure 0-5 East Moorabool River at Egerton Bungeeltap Road, Transect 3 cross section.**

1.1.6 Ecological objectives

Based on the information obtained from the background review and the field inspection, ecological objectives have been developed for Reach 1 (Table 0-1).

Table 0-1 Ecological objectives for Reach 1.

Fish	No.	Process	Rationale	Timing of flow component	Relevant flow component
Restore self-sustaining population of Mountain Galaxias	F1a	Habitat – resting/rearing	Low flows provide adequate habitat all year (depth)	All year	Low
	F1b	Habitat – resting/rearing	High flows maintain the pools in channel form	Winter	High
	F1c	Breeding/Recruitment	Possibly move upstream to spawn in the headwaters which is triggered by a rise in water level.	Winter/Spring	Freshes
Maintain self-sustaining population of Australian Smelt	F2a	Habitat	Low flows provide adequate habitat all year (depth)	All year	Low
	F2b	Movement	Restricted habitat (upstream movement in Barwon recorded by Tunbridge).	Spring/Summer Winter/Spring	Freshes High
Restore self-sustaining population of River Blackfish	F3a	Habitat	Low flows provide adequate habitat all year (depth)	All year	Low
	F3c	Movement	No apparent migration. Movement is generally limited to a home range 25 to 30 m, no spawning migration	Spring/Summer	High
Restore self-sustaining population of Southern Pygmy Perch	F4a	Habitat	Low flows provide adequate habitat all year (depth)	All year	Low
Maintain self-sustaining population of Short-finned Eel	F5a	Habitat – resting/rearing	Low flows provide adequate habitat all year (depth)	All year	Low
	F5b	Movement	Upstream migration as elvers	Spring/Summer	High flows
Macroinvertebrates	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Maintain a diverse macroinvertebrate community consisting of both slow water (Coenagrionidae) and fast water (Hydropsychidae) species.	M1	Disturbance	Reset macroinvertebrate community by alteration of habitat	Winter/Spring Summer	Freshes Cease to flow
	M2	Habitat maintenance	Restore riffle habitat by removing accumulated sediment	Winter/Spring	Freshes
	M3	Habitat availability	Maintain riffle habitat	Winter	Low

Vegetation	No.	Process	Rationale	Timing of flow component	Relevant flow component
Maintain in-stream macrophyte species diversity	V1a	Colonisation	Most species flower in the low flow season when they are less prone to damage	Spring	Low
	V1b	Disturbance	Maintain instream species diversity	Summer	Cease to flow
Limit encroachment of emergent in-stream vegetation and species common to non-flowing waterbodies such as Cumbungi	V2	Habitat maintenance	In-stream vegetation in this reach is dominated by cumbungi which choke the channel and prevent flow downstream.	Winter/Spring	Freshes/High
Maintenance of riparian vegetation communities (eg tea-tree).	V3	Wetting	Establishment and growth of riparian species	Winter	High
Habitat/Processes	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Re-shape in-channel forms to maintain physical habitat diversity and complexity	H1	Transport of sediment	Flush sediment to maintain pool habitat	Any time	Freshes/High
Maintain physical processes	H2	Organic matter transport	Flush organic matter through system that has accumulated in pools and transfer carbon energy downstream	Winter/Spring	High
Maintain woody debris/snag habitat	H3	Submergence	Maintain habitat for fish and macroinvertebrates	Anytime	Low
Water quality	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Rehabilitate dissolved oxygen in pools and during periods of low flow	W1	Habitat maintenance/mixing	No evidence of issues from water quality data. However downstream of bridge on Bungeeltap Road, river widens, flow is slow and accumulated scum was visible on the surface	Summer Winter	Freshes
Rehabilitate total phosphorus concentrations	W2	Habitat maintenance	Six of the seven years since 1996, total phosphorus has exceeded SEPP objectives	Summer	Freshes
Rehabilitate electrical conductivity	W3	Habitat maintenance	Electrical conductivity can be quite high at times and may be the result of groundwater inflow.	Summer	Freshes

1.1.7 Flow recommendations

Flow recommendations have been provided for the flow components described below. A summary of the recommendations for Reach 1 is shown in Table 0-2.

Summer cease to flow

Naturally, this reach was characterised by a long summer cease to flow period as the headwaters dried (Figure 0-6). Cease to flow periods create disturbance that helps to maintain instream macrophyte and macroinvertebrate species diversity. The alteration in habitat structure brought about by cease to flows alters the macroinvertebrate species composition by eliminating some species (ie. grazers) and allowing other species to recolonise (Lake, 2003). The recommendation for a flow of 0 ML/d should occur at a maximum of twice per year in order to replicate the natural frequency and ensure that water quality within isolated pools does not deteriorate such that dissolved oxygen levels are lethal (Figure 0-7). Duration of 30 days is recommended to ensure that species within this reach are adequately disturbed and displaced but an increase in nutrient concentration and high temperatures do not precipitate algal blooms.

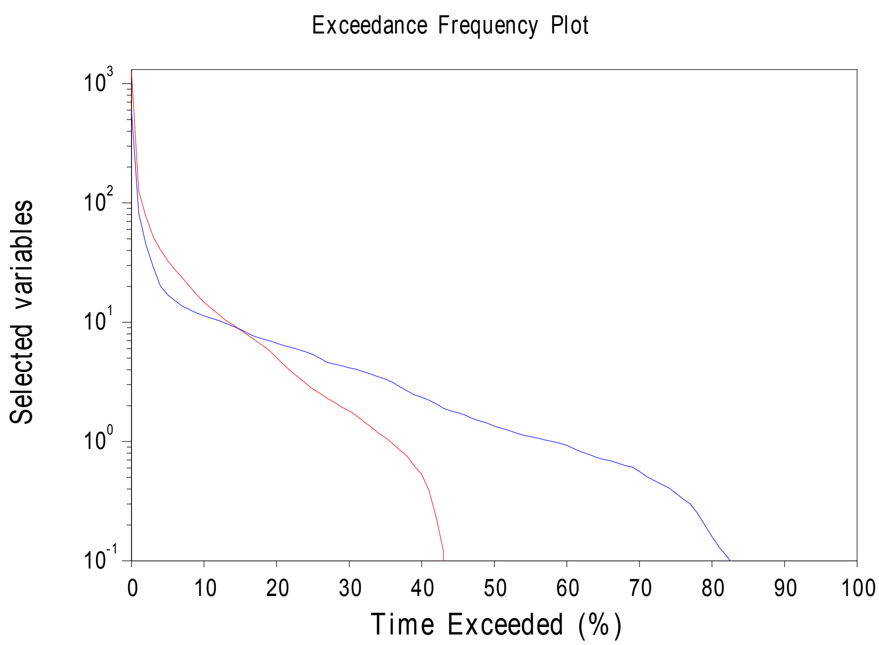


Figure 0-6 East Moorabool River summer flow duration. Dashed red line – natural, solid blue line – current.

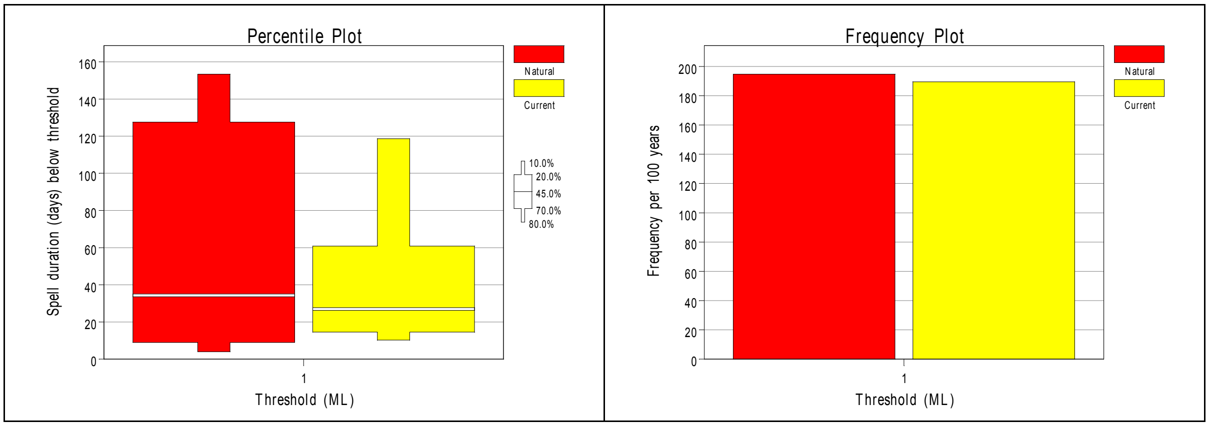


Figure 0-7 Duration (left) and frequency (right) of East Moorabool River summer spells below 1 ML/d under natural and current conditions in Reach 1.

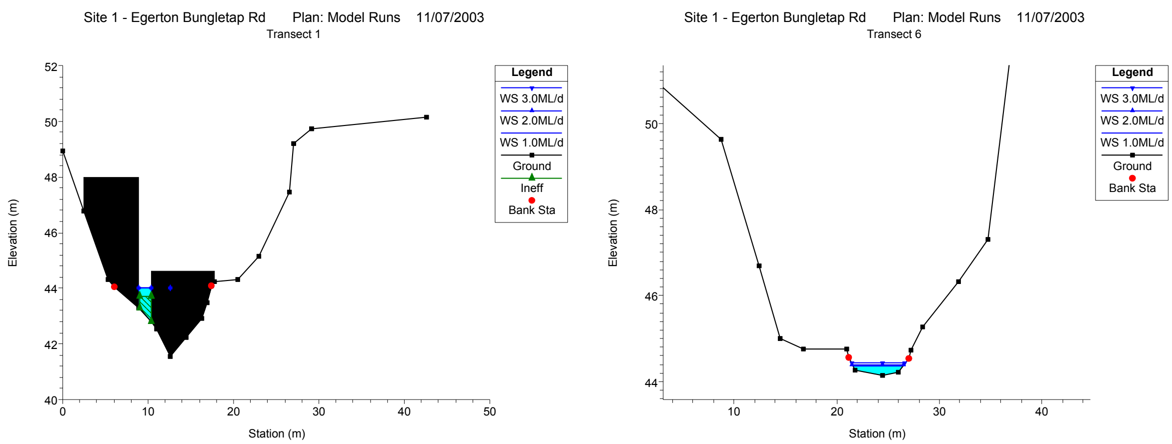
Summer low flow

No summer low flow recommendation has been made for this reach. Given the site features of deep pools separated by shallow riffles and macrophytes, a summer low flow would not have been expected. Analysis also reveals low flow percentiles of 70, 80 and 90 correspond to cease to flow periods. Summer low flow periods therefore did not occur naturally and cease to flow periods would have naturally been interrupted by summer freshes and high flow periods (Figure 0-6).

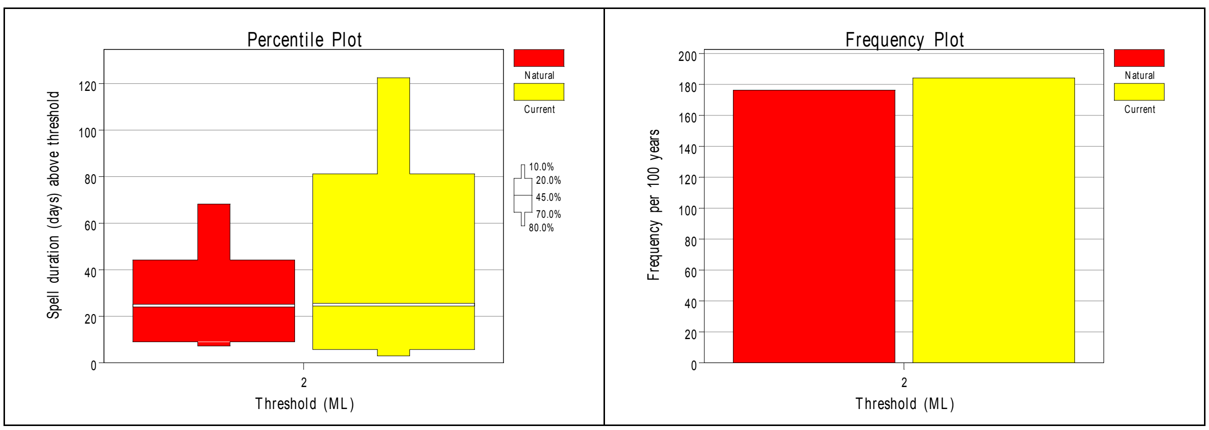
Summer – fresh

The recommended summer fresh flow of 2 ML/d is above the summer median flow of 1ML/d. This is to ensure adequate depth and velocity is achieved in the smaller cross sections in order to provide greater connectivity to the pools for the rehabilitation of water quality. An increase from 1 to 2 ML/d in the riffle at Transect 6, doubles the velocity from 0.01 m/s to 0.2 m/s and increases the depth from 22 cm to 26 cm (Figure 0-8).

This flow should occur at a minimum of twice per year in order to replicate the natural frequency and to allow the flushing and mixing effect to be cumulative (Figure 0-9). It should last for 10 days to ensure significant hydrological inputs are delivered to the pools.



▪ **Figure 0-8 Stage height at Transect 1 (left) and Transect 6 (right) for trialed summer fresh flows of 1, 2 and 3 ML/d at Reach 1.**



▪ **Figure 0-9 Duration (left) and frequency (right) of East Moorabool River summer spells above 2 ML/d under natural and current conditions in Reach 1.**

Winter – low flow

The recommended winter minimum flow of 8 ML/d is the 70% flow for the winter period June to November. It provides increased velocity and depth in the riffle habitat for movement of fish species without inundating the benches (Figure 0-10). Flows lower than 2 ML/d would provide significantly less velocity in the riffle habitat (0.05 to 0.02 m/s) and reduced channel wetting (5.75 to 5.04 m top width).

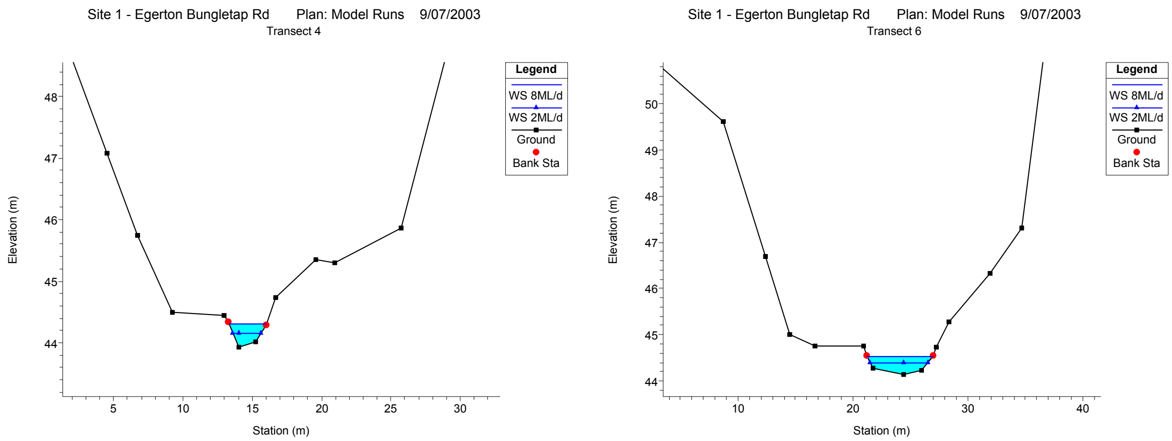
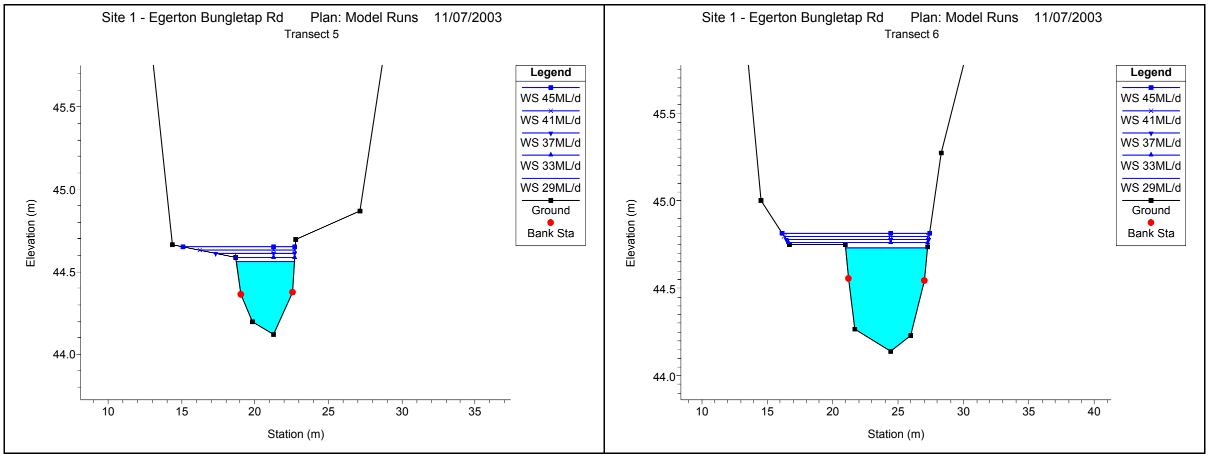


Figure 0-10 Stage height at Transect 4 (left) and Transect 6 (right) for trialed winter low flows of 2 and 8 ML/d at Reach 1.

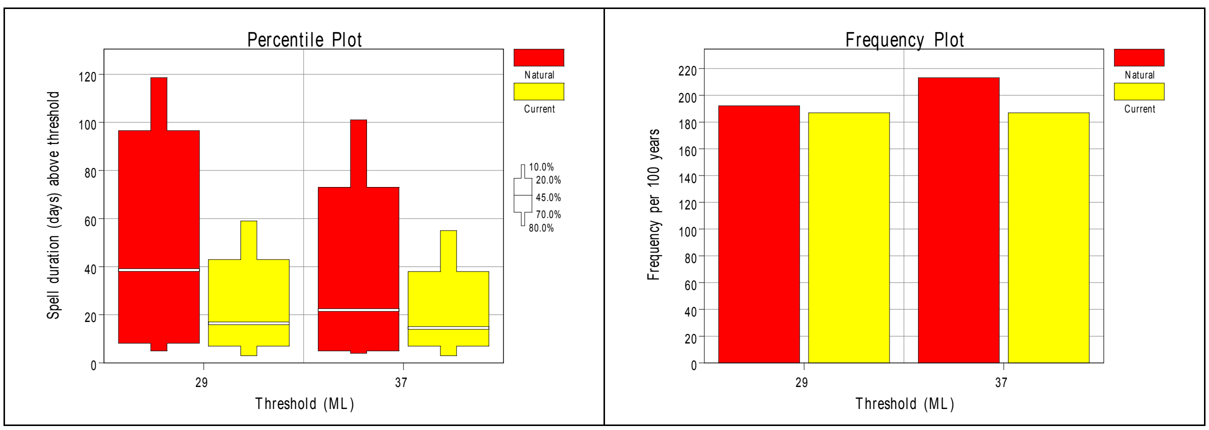
Winter – fresh

The recommended winter fresh flow of 37 ML/d will ensure the majority of benches are inundated in order to entrain organic matter and assist in the reduction of cover of terrestrial exotic grasses to a more natural vegetation mosaic. In addition, it will provide a biological cue for Mountain Galaxias to spawn. Mountain Galaxias have not been found within this reach, however are located on the West Moorabool. For this species to be reinstated and sustainable populations maintained within this reach, the appropriate flow cues for recruitment must be provided.

Naturally, median winter flows are about 29 ML/d or greater. However flows of this magnitude do not perform the function of inundating the banks, particularly at Transects 5 and 6 (Figure 0-11). The recommended flow of 37 ML/d should occur at a minimum of twice a year because often one event is not considered effective alone as a biological cue. Naturally this flow would occur at approximately 45% of the time for 20 days (Figure 0-12). However, duration of 10 days is recommended to maintain the natural duration of 70% of the natural events and allow for the recolonisation of native species that favour frequent flooding.



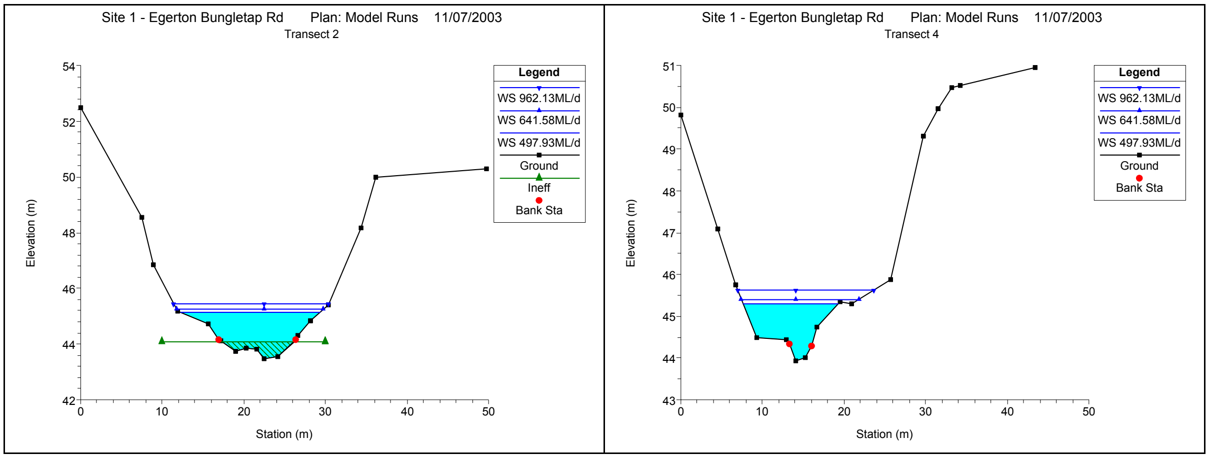
▪ **Figure 0-11 Stage height at Transect 5 (left) and Transect 6 (right) for trialed winter fresh flows of 45, 41, 37, 33, and 29 ML/d.**



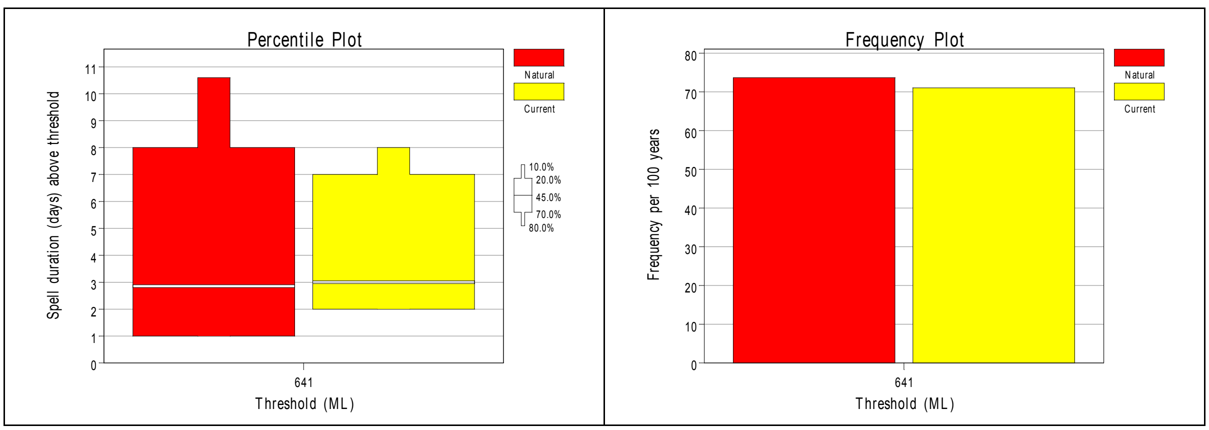
▪ **Figure 0-12 Duration (left) and frequency (right) of winter spells above 29 and 37 ML/d under natural and current conditions in Reach 1.**

Winter – high flow

Winter high flows are recommended to flatten the Cumbungi and allow organic matter to move through the channel providing energy and a food source to organisms downstream. As the channel has a broad bench, increased habitat area and thorough inundation of the channel will be achieved at flows greater than 641 ML/d. This flow also corresponds to the annual return high flow. A reduction in flow to say, 498 ML/d will not provide adequate depth along the margins, which is particularly evident at Transects 2 and 4 (Figure 0-13). The recommended duration of 1 to 3 days is 45 to 75% of the natural events and is considered a suitable period for which to scour or redistribute sediment that has built up over low flow periods (Figure 0-14).



■ **Figure 0-13 Stage height at Transect 2 (left) and Transect 4 (right) for trialed winter high flows of 962, 641, and 498 ML/d.**



■ **Figure 0-14 Duration (left) and frequency (right) of winter spells above 641 ML/d under natural and current conditions in Reach 1.**

▪ Table 0-2 Flow recommendations for Reach 1.

River	East Moorabool River			Reach	East Moorabool River – Bostock Reservoir to the confluence with the West Moorabool River
Flow					Rationale
Season	Flow component	Magnitude	Frequency	Duration	Objective
Summer Dec - May	Cease to flow	0 ML/d	Maximum twice annually	30 days	M1, V1b
	Low flow	NR			
	Fresh	> 2 ML/d	Minimum twice annually	10 days	F2b, F3c, F5b, H1, H2, W1, W2, W3
Winter Jun - Nov	Low flow	8 ML/d	Annual	Jun - Nov	F1a, F2a, F3a, F4a, F5a
	Fresh	> 37 ML/d	Minimum twice annually	10 days	F1b, M1, M3, V1a, V2, H3
		> 641 ML/d	Once a year	1 - 3 days	F2b, M2, V3, H1, H2

NR – No flow recommendation made

1.2 Reach 2: West Moorabool River between Moorabool and Lal Lal Reservoirs

1.2.1 Reach description

The upper reach of the West Moorabool River between Moorabool and Lal Lal Reservoirs is characterised by a contracted channel that meanders through pastureland (Figure 0-15, Figure 0-16).

Here, the riparian vegetation is dominated by willows and pasture grasses. The instream vegetation was similarly in poor condition – due in part to grazing, stock access and low flow. However, aquatic macrophytes such as Ribbonweed and rush were present at Yendon- Egerton Road. Oil was also visible on the water surface at this site.

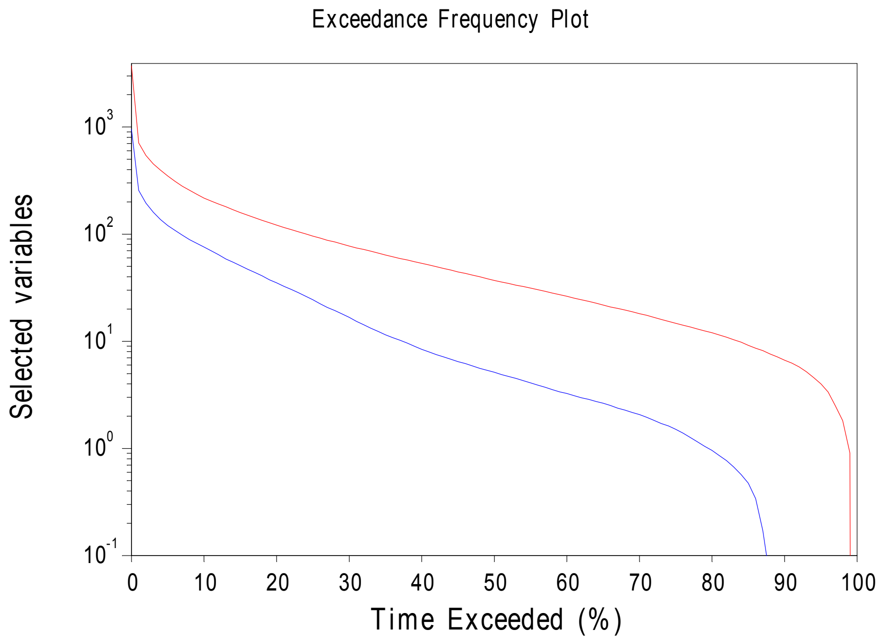
No surveying was undertaken within this reach as the channel is narrow and contracted with few habitat features, meaning that little change would have been observed with modelled flows. As such, an additional site was surveyed downstream of Lal Lal Reservoir at Elaine-Egerton Road. The hydraulic model at this site was used to model the flows upstream of Lal Lal Reservoir and determine the effects and therefore suitability of flow recommendations for upstream of Lal Lal Reservoir. This was only conducted for summer and winter low flows.

■ **Figure 0-15 West Moorabool at Butter factory Road (March 2003).**

■ **Figure 0-16 West Moorabool at Yendon Egerton Road looking downstream (March 2003).**

1.2.2 Hydrology

The flow duration curve shows that cease to flow periods are an infrequent occurrence within this reach (Figure 0-17). Currently, there has been an increase in cease to flow events and decrease in overall flow due to the impoundment of water at Moorabool Reservoir. It should be noted that natural flows are calculated with the impact of farm dam and groundwater extraction taken out.



▪ **Figure 0-17 West Moorabool River between Moorabool and Lal Lal Reservoirs daily flow duration of all months. Dashed red line – natural, solid blue line – current.**

1.2.3 Environmental values

Limited fish survey data is available for this reach, but indicates that exotic species including Redfin, Brown Trout and Tench (*Tinca tinca*) dominate. Only one native fish species, Mountain Galaxias has been recorded in this reach and occurs as far downstream as She Oaks. Fish species within this reach are isolated due to the presence of barrier upstream (Moorabool Reservoir) and downstream (Lal Lal Reservoir).

One ISC site is present within this reach. However no aquatic life (ie. SIGNAL and AUSRIVAS) scores are available.

A total of 11 Victorian threatened water dependent bird species have been recorded within the Moorabool River catchment downstream of Moorabool Reservoir and Bostock Reservoir (NRE, 1999b) (**Error! Reference source not found.**). This list includes the critically endangered Little Egret and Intermediate Egret and the endangered Great Egret. Five species are listed under the *FFG Act 1998*. The Great Egret is also declared internationally significant by the Japan and Australia Migratory Bird (JAMBA) and China and Australian Migratory Bird (CAMBA) Agreements.

1.2.4 Water quality

Water quality monitoring within this reach is conducted at Lal Lal (VWQMN site 232210). A summary of water quality data at this site and comparison to the draft SEPP objectives (EPA,

2001) and the ANZECC water quality guidelines (ANZECC, 2000) is provided in **Error! Reference source not found.**.

Total nitrogen concentrations have exceeded all draft SEPP objectives since 1992 and two algal blooms have occurred in the Moorabool Reservoir during 1980 and 1991. Dissolved oxygen complied for the four years in which percentiles could be calculated (1992-3, 2001-2). Turbidity and total phosphorus complied with the draft SEPP objectives four out of the eight and three out of the nine years for which monitoring was undertaken. pH has met the draft SEPP objective during six of the ten years since 1992 for which monitoring was undertaken.

1.2.5 Issues

The natural flow regime in this reach has been significantly altered due to the impoundment of water at Moorabool Reservoir. Compared to natural, there has been an increase in cease to flow events and decrease in median flows (18 to 2 ML/d). The absence of these natural mechanisms has created conditions more favourable to exotic species such as Brown Trout and Redfin. Populations of these species are likely to impact on populations of native aquatic fauna either indirectly through alteration of in-stream habitat or directly through competition for food and shelter and predation on small-bodied species in early life history stages (e.g. Brown Trout).

Extensive clearing of the riparian zone in the upper catchment, combined with stock access has resulted in the dominance of exotic species such as willows and pasture grasses. Encroachment of the stream channel by these grasses reduces habitat availability, complexity and diversity and represents a potential risk to aquatic biota. Low flows also favour the presence of filamentous algae.

1.2.6 Ecological objectives

Based on the information obtained from the background review and the field inspection, ecological objectives have been developed for Reach 2 (Table 0-3).

▪ Table 0-3 Ecological objectives for Reach 2.

Fish	No.	Process	Rationale	Timing of flow component	Relevant flow component
Maintain self-sustaining population of Mountain Galaxias	F1a	Habitat – resting/rearing	Low flows provide adequate habitat all year (depth)	All year	Low
	F1b	Habitat – resting/rearing	High flows maintain the pools in channel form	Winter	High
	F2a	Breeding/Recruitment	Possibly move upstream to spawn in the headwaters which is triggered by a rise in water level.	Winter/Spring	High flows
	F2b	Breeding/Recruitment	Possibly move upstream to spawn in the headwaters which is triggered by a rise in water level.	Winter/Spring	Freshes
Macroinvertebrates	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Maintain a diverse macroinvertebrate community consisting of both slow water (Coenagrionidae) and fast water (Hydropsychidae) species.	M1	Disturbance	Creation of a new habitat for a variety species introduced by recolonisation.	Winter/Spring Summer	Freshes Cease to flow
	M2	Habitat maintenance	Restore riffle habitat by removing accumulated sediment	Winter/Spring	Freshes
	M3	Habitat availability	Maintain riffle habitat	Spring/Summe r	Low
Vegetation	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Maintain in-stream macrophyte species diversity	V1	Colonisation	Most species flower in the low flow season when they are less prone to damage.	Spring	Low
Limit encroachment of in-stream vegetation and species common to non-flowing waterbodies such as Elodea and pasture grasses.	V2	Habitat maintenance	In-stream vegetation can be dominated by species common to non-flowing water bodies. Fast running waters are not favourable habitat for free-floating species or those with floating leaves	Winter/Spring	Freshes/High
Maintenance of riparian vegetation communities (eg. Silver Wattle and Blackwood).	V4	Wetting	Establishment and growth of riparian species	Winter	High

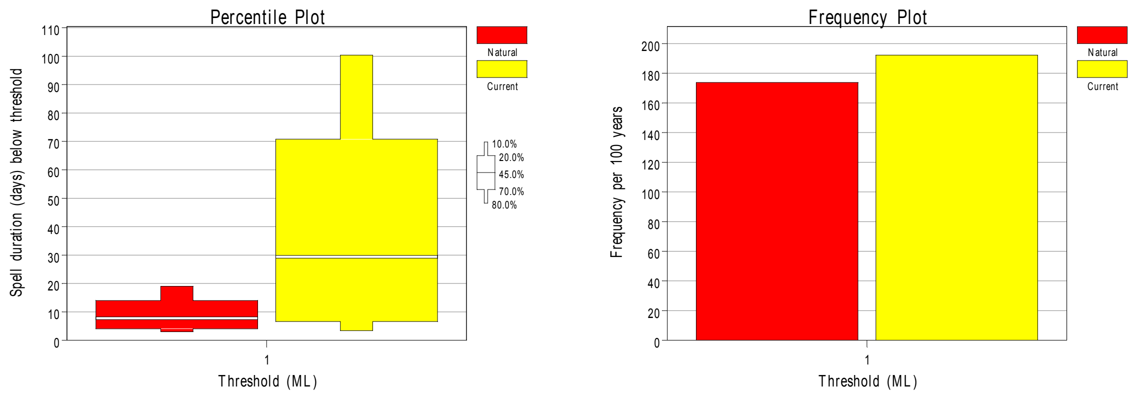
Habitat/Processes	No.	Process	Rationale	Timing of flow component	Relevant flow component
Re-shape in-channel forms to maintain physical habitat diversity and complexity	H1	Transport of sediment	Flush sediment from behind weir and maintain pool habitat	Any time	Freshes/High
Maintain physical processes	H2	Organic matter transport	Flush organic matter through system that has accumulated in pools and perhaps behind weirs	Winter/Spring	High
Maintain woody debris/snag habitat	H3	Submergence	Maintain and habitat for fish and macroinvertebrates	Anytime	Low
Water quality	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Rehabilitate dissolved oxygen in pools and weir-pools during periods of low flow	W1	Habitat maintenance/mixing	Dissolved oxygen is not monitored but could be low at times due to low flows.	Spring	Freshes
Rehabilitate total nitrogen concentrations	W2	Habitat maintenance	Total nitrogen concentrations have exceeded the SEPP objective since 1992.	Summer	Low
Rehabilitate electrical conductivity	W3a	Habitat maintenance	Electrical conductivity can be quite high and may be the result of groundwater inflow.	Summer	Low

1.2.7 Flow recommendations

Flow recommendations have been provided for the flow components described below. A summary of the recommendations for Reach 2 is shown in Table 0-4.

Summer – cease to flow

A cease to flow event is recommended to create disturbance that helps to maintain instream macrophyte and macroinvertebrate species diversity. Currently, cease to flow events occur more frequently and for a longer duration than what naturally occurred due to extractions (Figure 0-18). It is recommended that the frequency of cease to flow events should decrease to a maximum of two per year so as to replicate the natural frequency and prevent the encroachment of exotic pasture grasses in the channel. Duration of eight days is recommended for the effect to be cumulative.



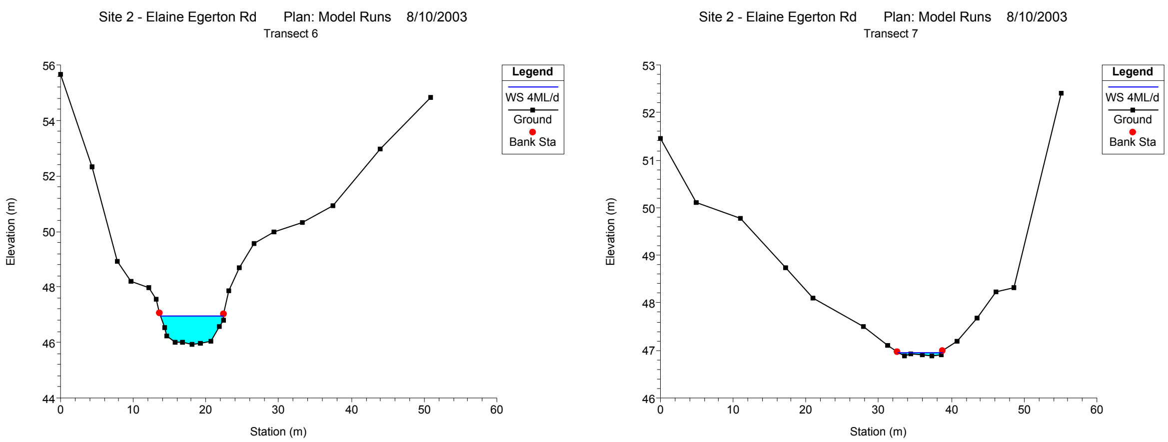
▪ **Figure 0-18 Duration (left) and frequency (right) of summer spells below 1 ML/d under natural and current conditions in Reach 2.**

Summer – low

A low flow of 4 ML/d is recommended for Reach 2. This recommendation is based on 70th percentile exceedence flow for daily summer flows upstream of Lal Lal Reservoir. As no hydraulic model was developed for this reach upstream of Lal Lal Reservoir, the hydrology from this reach was entered into a hydraulic model downstream of Lal Lal Reservoir. This was used to determine the suitability of flow recommendations for this reach.

A flow of 4 ML/d downstream of Lal Lal Reservoir will wet the bottom of the channel and therefore maintain minimum habitat conditions for aquatic biota. HEC-RAS outputs indicate that a flow of this magnitude would provide a depth of 1.04 m in the deepest pool at Transect 6 and 7 cm in the riffle habitat at Transect 7 (Figure 0-19; Figure 0-20). These depths will enable adequate fish passage between the high and low flow habitats, yet leave the benches exposed for entrainment and weathering of organic matter. This would be an adequate flow recommendation for upstream of Lal Lal Reservoir.

▪ **Figure 0-19 Site surveyed downstream of Lal Lal Reservoir – Transect 7, riffle habitat.**

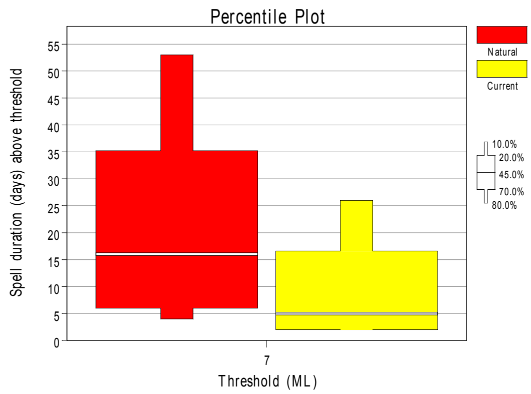


▪ **Figure 0-20 Stage height at Transect 6 (left) and Transect 7 (right) for the summer low flow threshold of 4 ML/d.**

Summer – fresh

The recommended summer fresh flow of 7 ML/d will limit the further encroachment of exotic pasture grasses present in the contracted channel as well as improving water quality by flushing and turning over the pools. By increasing the flow from a summer low, depth will also be increased. This will enhance connectivity between pools and provide a great variety of habitats within the degraded channel.

Under natural conditions, flows that exceeded the recommended threshold for summer freshes would have lasted for an average of 16 days and occurred nearly five times a year during the low flow period (Figure 0-21). Under current conditions, flows exceeding the threshold occurred less often, about twice a year and tended to be shorter in duration. This change would have had significant impacts on water quality and channel form. It is therefore recommended that summer freshes be provided at least four times a year and for a minimum duration of seven days. The ecological benefits provided by freshes only require a relatively short duration and seven days is considered adequate to provide wetting and improve water quality. However the benefits are also relatively short lived so more than one fresh is required over the summer low flow period. A frequency of four per year will mimic natural conditions and if interspersed across the low flow period help maintain habitat quality.



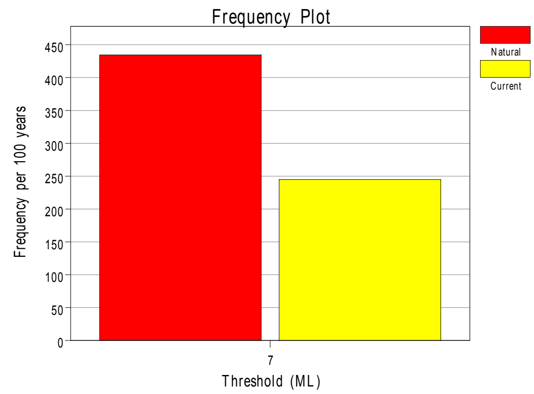
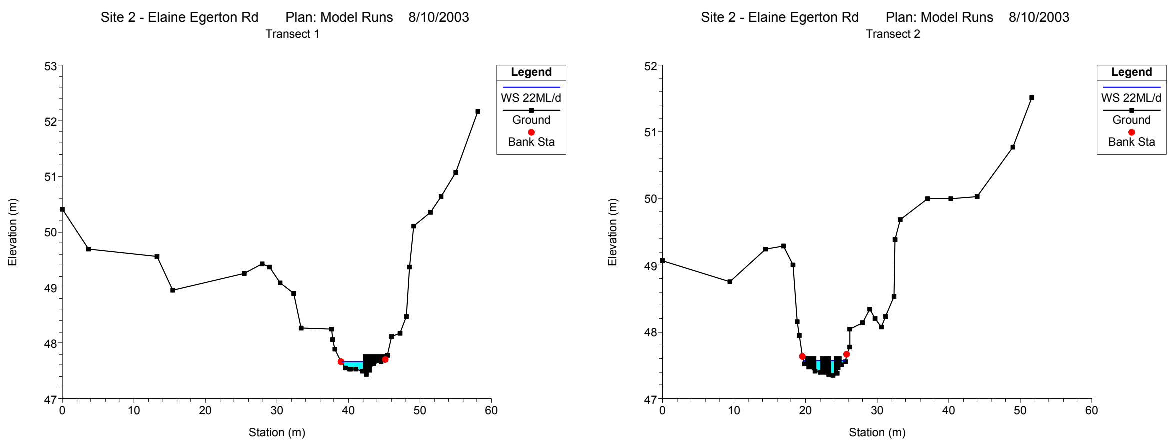


Figure 0-21 Duration (left) and frequency (right) of summer spells above 7 ML/d under natural and current conditions.

Winter – low

The recommended winter low for Reach 2 is 22 ML/d. As with the summer low flow, this recommendation is based on the 70th percentile exceedence flow for daily winter flows upstream of Lal Lal Reservoir. Again, as no hydraulic model was developed for this reach, the hydrology from this reach was entered into a hydraulic model downstream of Lal Lal Reservoir to determine the suitability for the recommendations upstream.

The recommended flow of 22 ML/d will provide minimum habitat conditions for the winter period by maintaining connection between the shallow and deeper pools. This is evidenced by an increase in wetted area and depth of 11 cm at Transect 1 and 13 cm at Transect 2, compared to summer low flows (Figure 0-22).

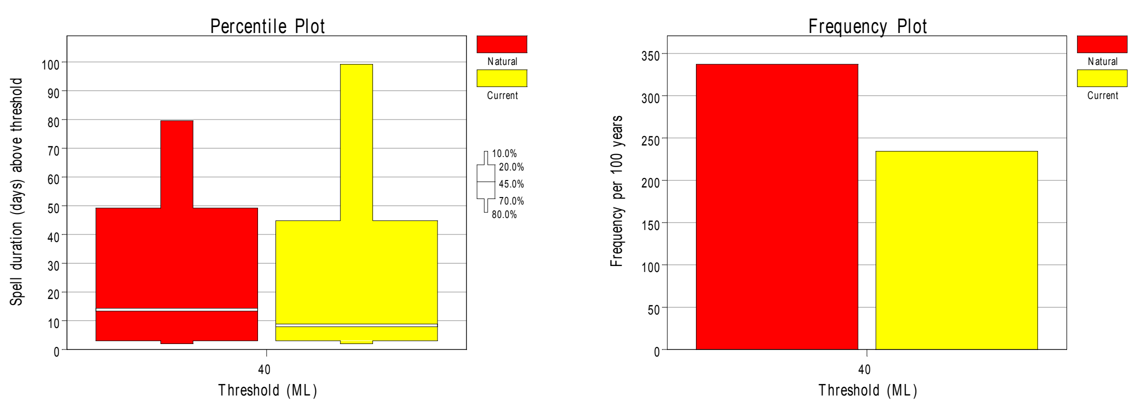


■ **Figure 0-22 Stage height at Transect 1 (left) and Transect 2 (right) for recommended winter low flow threshold of 22 ML/d.**

Winter – fresh

This reach is characterised by high level eroded benches as a result of stock access and willow growth. A winter fresh flow of 40 ML/d will inundate the margins of these benches and assist in the reduction of cover of terrestrial exotic grasses favoured by low hydrological stability. When the flow expands into the riparian zone, organic matter will also be entrained and carried downstream where it will provide food and energy. In addition, it will provide a biological cue for Mountain Galaxias to spawn.

Compared to natural conditions, flows of this magnitude occurred more frequently and for a similarly long duration (Figure 0-23). It is recommended that winter freshes be allowed to occur at a minimum of three times per year for a minimum of ten days duration to provide an adequate degree of disturbance to terrestrial vegetation.

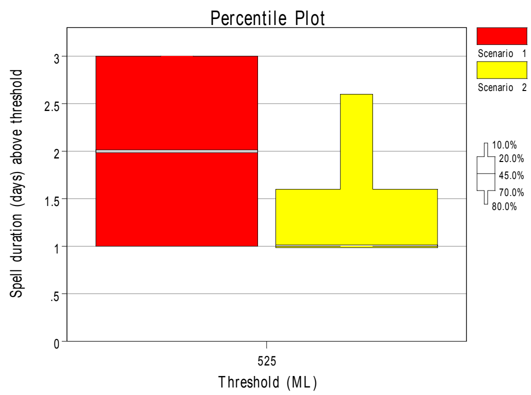


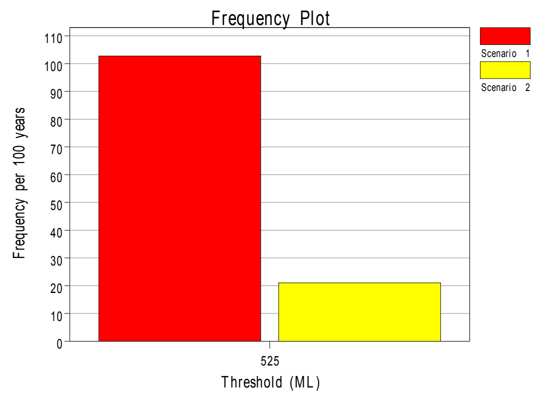
■ **Figure 0-23 Duration (left) and frequency (right) of winter spells above 40 ML/d under natural and current conditions in Reach 2.**

Winter – high

A winter high flow of 525 ML/d is recommended for Reach 2. It is envisaged that this flow would almost fill the entire channel, inundating all benches, wetting and disturbing riparian vegetation and transporting sediment downstream.

Currently, flows of this magnitude occur for a much short duration (less than 1 day) and frequency (less than 20 in 100 years) (Figure 0-24). Naturally this flow corresponds to the annual return flow. This flow is recommended to occur annually for a minimum duration of 1 –2 days. This is considered a suitable period for which to scour or redistribute sediment that has built up over low flow periods.





- **Figure 0-24 Duration (left) and frequency (right) of winter spells above 525 ML/d under natural and current conditions in Reach 2.**

- **Table 0-4 Flow recommendations for Reach 2.**

River	West Moorabool River			**Reach**	West Moorabool River – Moorabool to Lal Lal Reservoirs
Flow					**Rationale**
Season	**Flow component**	**Magnitude**	**Frequency**	**Duration**	**Objective**
Summer Dec - May	Cease to flow	0 ML/d	Maximum twice annually	8 days	F1a, M1, V1b
	Low flow	4 ML/d	Annual	Dec - May	W1
	Fresh	> 7 ML/d	Minimum four per year	7 days	H1, H2, W1, W2, W3
Winter Jun - Nov	Low flow	22 ML/d	Annual	Jun - Nov	F1a, M1
	Fresh	> 40 ML/d	Minimum three per year	10 days	F2b, M1, M3, V1a, V2, H3
	High flow	525 ML/d	Once a year	1 – 2 days	F2a M2, V3, H1, H2

1.3 Reach 3: West Moorabool River below Lal Lal Reservoir to Sharp Road, She Oaks

This reach is located in the middle of the Moorabool River catchment and includes the west branch of the Moorabool River downstream of Lal Lal Reservoir to Sharp Road downstream of She Oaks Weir.

This reach contains some of the most valuable instream and riparian habitats in the catchment - partly due to the fact that the Brisbane Ranges National Park and Steiglitz Historical Park border the river to the east upstream of She Oaks. Downstream of Lal Lal Reservoir at Elaine Egerton Road vegetation such as River Red Gum, Silver Wattle and Woolly Tea-tree are present (Figure 0-25, Figure 0-26). Immediately downstream of the confluence in the vicinity of Morrisons, the presence of River Red Gum declines and impact of farming and willow removal is evident (Figure 0-27).

The channel in this reach varied from constricted and choked by Cumbungi in the vicinity of Morrisons to very wide and shallow downstream at Steiglitz Road. A variety of hydraulic habitats was also present throughout the reach and included large and small pools separated by natural riffles. Just below the confluence, the substrate consisted of cobbles, whereas further downstream bedrock and fine sand was dominant (Figure 0-28). However widening and deepening may be accelerated due to sustained high flows from Lal Lal Reservoir to She Oaks.

- **Figure 0-25 West Moorabool River below Lal Lal Reservoir, Hunts Bridge Transect 5 cross section (May 2003).**

- **Figure 0-26 West Moorabool River below Lal Lal Reservoir, Hunts Bridge Transect 5 upstream (May 2003).**

▪ **Figure 0-27 Moorabool River at Morrisons gauging station looking upstream (March 2003).**

▪ **Figure 0-28 Moorabool River at Morrisons gauging stations looking downstream (March 2003).**

1.3.1 Site description

One site within this reach was surveyed. It was located immediately downstream of She Oaks Weir at Sharp Road. Here, a long deep pool separated when the river bifurcated downstream of the bridge at Transects 2 and 3. A large bar between the channels was vegetated with pasture grasses and Woolly Tea-tree. Flow was diverted around the bar and a large fallen tree to the right, leaving the smaller channel to the left with no flow. This channel during the site visit was still quite wet and contained a large amount of woody debris and leaf litter. Riffles were present immediately upstream and downstream of the bifurcation at Transects 2 and 4.

Riparian vegetation at the site consisted of River Red Gum over dense scrub consisting of Woolly Tea-tree, Silver Wattle and bottlebrush (Figure 0-29). Instream species were sparse and consisted of rush and Common Reed (*Phragmites australis*). Blackberries densely lined the left bank for approximately 100 m between Transects 3 and 4.

The left bank at this site was flat where walking and car access to the adjoining park was evident. At Transect four the basalt bank became steeply graded and levelled off again at Transect 7 where a large pool and swimming hole was present. Farming was evident over the top of the hill.

The right bank was only assessable by crossing the river. It was densely vegetated with eucalypts and tea-tree. A high flow channel here was unable to be surveyed.

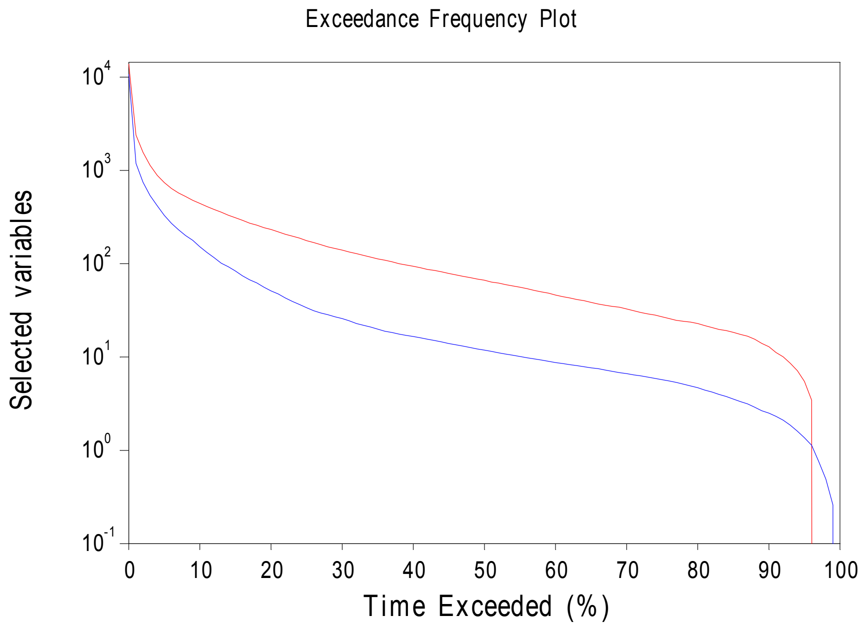
The substrate at the site consisted of bedrock in the pools, and cobbles and pebbles in the riffles (Figure 0-30). Transect 3 contained a deep gravel depression within the vegetated bar. Woody debris had accumulated just upstream and within the bar.

■ **Figure 0-29 Moorabool River Sharp Road downstream of She Oaks Weir, Transect 1 cross section.**

■ **Figure 0-30 Moorabool River Sharp Road downstream of She Oaks Weir, Transect 6 looking upstream.**

1.3.2 Hydrology

Naturally flow in this reach would be variable. However constant flows, lower than what naturally occurs, are present due to this reach being used as a conduit for delivering water to She Oaks Weir and subsequently Geelong (Figure 0-31).



▪ **Figure 0-31 West Moorabool River Lal Lal Reservoir to below She Oaks at Sharps Road. Dashed red line – natural, solid blue line – current.**

1.3.3 Environmental values

Four native fish species have been recorded from the Moorabool River downstream of Lal Lal Reservoir to She Oaks Weir (Table 0-5). Of these, River Blackfish and Australian Smelt have a wide distribution in the Moorabool River that extends from the junction with the Barwon River to the junction with Coolebarghurk Creek (running up past Meredith) (NRE, 2003a).

Short-finned Eel are the only migratory species recorded upstream of She Oaks weir. The decrease in species richness and particular lack of migratory species upstream of She Oaks is most likely due to the presence of She Oaks Weir.

A number of other native fish species including Australian Grayling, Common Galaxias and Spotted Galaxias have been recorded further downstream in the vicinity of Batesford. Their distribution as far upstream of She Oaks is probable, but doubtful, considering a number of weirs downstream of She Oaks. Environmental flow recommendations have been provided for with these species in mind.

Table 0-5 Fish species recorded in the West Moorabool River below Lal Lal Reservoir to She Oaks Weir (NRE, 2003a; Zampatti and Grgat, 2000).

Scientific name	Common name	Victorian conservation status	Migratory	Last observed
Gadopsis marmoratus	River Blackfish	Common	N	1998
Anguilla australis	Short-finned Eel	Common	Y	1998
Retropinna semoni	Australian Smelt	Common	N	1998
Nannoperca australis	Southern Pygmy Perch	Common	N	1998

The Environment Protection Authority (EPA) sampled the Moorabool River for macroinvertebrates at Sharp Road, She Oaks on four occasions. Two habitats (edge/pool, kick/riffle) were sampled from the EPA site in the autumn and spring of 1998 and 2000. The results of the combined data from the two seasons were compared against the draft SEPP macroinvertebrate objectives for regions classed as cleared hills and coastal plains (EPA, 2001). The indicators met all the respective EPA objectives and well exceeded the number of families and key families typically found in streams of this region. This indicates that in general, at this site, the macroinvertebrate community diversity is high and is not limited by habitat availability or water quality. Given the variety of hydraulic and substrate habitats within this reach, fast and slow flowing species such as net spinning caddis (Family: Hydropsychidae) and damselflies (Family: Coenagrionidae) would be present.

1.3.4 Water quality

Water quality within this reach is monitored at Morrisons (VWQMN site 232204). A summary of water quality data at this site and comparison to the draft SEPP objectives (EPA, 2001) and the ANZECC water quality guidelines (ANZECC, 2000) is provided in **Error! Reference source not found.**.

Total nitrogen has exceeded the draft SEPP objective for the last eleven years. However during the last four of these, 75th percentile concentrations have stabilised to within 0.01 to 0.09 mg/L. On the other hand, total phosphorus and turbidity have complied. Trend analyses conducted by Barton (2000) show that turbidity concentrations have generally decreased at Morrisons since 1980.

Electrical conductivity exceeded the SEPP guideline of ≤ 500 µS/cm ten out of the last eleven years and reached a record 75 % of 1450 in 2002. Dissolved oxygen was well above the ANZECC guideline of ≥ 6 mg/L.

1.3.5 Issues

Prolonged periods of low flow, reduced median flow and lack of flow variability have been identified as the primary issues impacting environmental values present within this reach. This is primarily the result of impoundment of water at Lal Lal Reservoir and the need to transfer water to She Oaks for Geelong's water supply. Flow variability is crucial in maintaining populations of native fish species and improving habitat diversity. Species such as Australian Grayling and Common Galaxias require flushing flows for spawning cues and upstream migration from the sea. These cues are essential in maintaining native fish populations.

She Oaks Weir forms a major barrier preventing fish movement further upstream into this reach (Figure 0-32). It is probable, but doubtful, that other native fish species currently found further downstream such as Australian Grayling and Tupong would migrate upstream to She Oaks weir due to the presence of a number a small weirs between She Oaks and Batesford. If this migration was possible, habitat for native fish species is favourable due to the presence of deep pools and a variety of hydraulic habitats in the vicinity of Sharps Road.

In the vicinity of Morrisons and downstream of Lal Lal Reservoir at Elaine-Egerton Road stock access was evident and has perhaps accelerated bank erosion. Riparian management including willow poisoning and removal is currently undertaken near the confluence at Morrisons. Willows invade stream channels creating localised hydraulic problems and smother and destroy native vegetation.

- **Figure 0-32 She Oaks Weir (March 2003).**

1.3.6 Ecological objectives

Based on the information obtained from the background review and the field inspection, ecological objectives have been developed for Reach 3 (Table 0-6).

▪ Table 0-6 Ecological objectives for Reach 3.

Fish	No.	Process	Rationale	Timing of flow component	Relevant flow component
Restore self-sustaining population of Australian Grayling	F1a	Habitat	Provide adequate habitat all year.	All year	Low
	F1b	Recruitment	Spawning possibly occurs when water levels rise (possibly mature adults migrate back upstream from sea to spawn). Spawn in same portion of river they inhabit	Spring/Summer	Freshes
	F1c	Movement	Upstream migration from sea at end of first year	Spring/Summer	High flows
Maintain self-sustaining population of Short-finned Eel	F2a	Habitat	Provide adequate habitat all year	All year	Low
	F2b	Movement	Upstream migration as elvers	Spring/Summer	High flows
Restore self-sustaining population of Common Galaxias	F3a	Habitat	Provide adequate habitat all year in pools	All year	Low
	F3b	Recruitment Movement	Juveniles migrate upstream from sea.	Spring/Summer	High
Restore self-sustaining population of Spotted Galaxias	F4a	Habitat	Provide adequate habitat all year in pools	All year	Low
	F4b	Recruitment	Juveniles migrate upstream from sea	Spring/Summer	High/Freshes
	F4c	Movement	Post-spawning move back upstream	Spring/Summer	High
Restore self-sustaining population of Short-headed Lamprey	F5a	Habitat	Provide adequate habitat all year in pools	All year	Low
	F5b	Recruitment	Downstream migration to sea (related to marked increases in freshwater discharge)	Autumn/Spring	Freshes/High flow
	F5c	Movement	Upstream spawning migration (reduced river flow and increased water temperature).	Spring/Summer	High
Restore self-sustaining population of Tupong	F6a	Habitat	Provide adequate habitat all year.	All year	Low
	F6b	Recruitment	Downstream spawning migration	Autumn/Winter	High
	F6c	Movement	Gradual upstream migration by juveniles	Winter	High
Maintain self-sustaining population of River Blackfish	F7a	Habitat	Provide adequate habitat all year in pools	All year	Low
	F7b	Movement	No apparent migration. Movement is	Spring	High

Fish	No.	Process	Rationale	Timing of flow component	Relevant flow component
			generally limited to a home range 25 to 30 m, no spawning migration		
Maintain self-sustaining population of Southern Pygmy Perch	F8	Habitat	Provide adequate habitat all year	All year	Low
Maintain self-sustaining population of Australian Smelt	F9a	Habitat	Provide adequate habitat all year	All year	Low
	F9b	Movement	Upstream movement through lower barrage in Barwon River (Koehn and O'Connor 1990)	Summer	Fresh
	F9c	Recruitment	Larvae washed to sea - In lower Barwon River, larvae not collected after high flows suggesting possibility that larvae are washed to sea (Koehn and O'Connor 1990). Diadromous populations have not been substantiated.	Winter	High
Macroinvertebrates	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Maintain diverse macroinvertebrate community consisting of both slow water (Coenagrionidae) and fast water (Hydropsychidae) species.	M1a	Disturbance	Reset macroinvertebrate community – colonisation by new species	Summer	Cease to flow
	M1b	Habitat maintenance	Restore riffles	Winter/Spring	Freshes
	M1c	Habitat availability	Maintain riffles	Spring/Summer	Low
Vegetation	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Maintain in-stream macrophyte species diversity	V2a	Colonisation	Colonisation	Spring	Low
	V2b	Disturbance	Maintain instream species diversity	Summer	Low/cease to flow
Limit encroachment of in-stream vegetation and species common to non-flowing water bodies such as Elodea and Azolla	V3	Disturbance	In-stream vegetation in the lower Moorabool can be dominated by species common to non-flowing water bodies	Winter/Spring	Freshes/High
Maintenance of riparian vegetation communities (eg. Silver Wattle and Blackwood).	V4	Wetting	Establishment and growth of riparian species	Winter	High

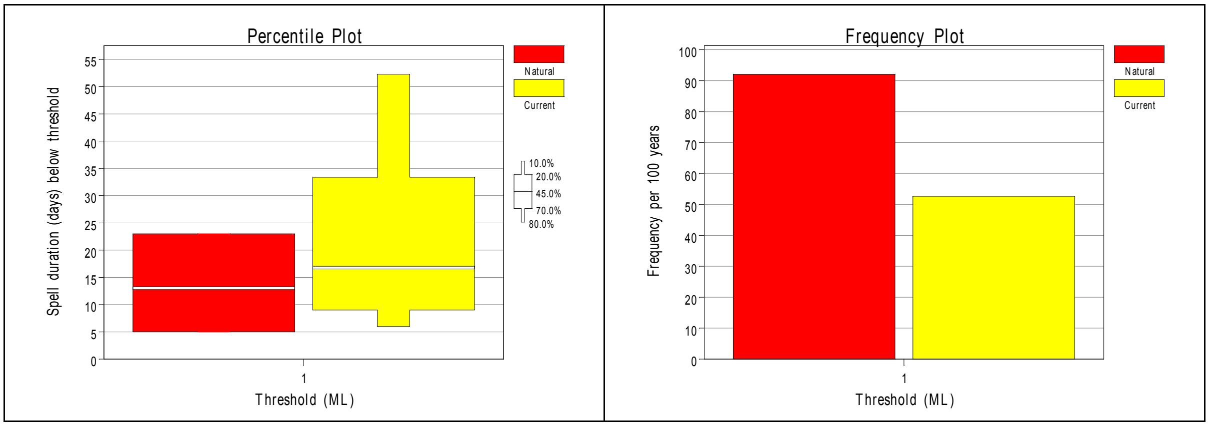
Habitat/Processes	No.	Process	Rationale	Timing of flow component	Relevant flow component
Re-shape in-channel forms to maintain physical habitat diversity and complexity	H1a	Transport of sediment	Flush sediment and maintain pool habitat	All year	High
Maintain physical processes	H1b	Organic matter transport	Flush organic matter through system that has accumulated in pools and perhaps behind weirs	Spring	High
Maintain woody debris/snag habitat	H2	Submergence	Bugs and fish (River Blackfish lay eggs on woody debris)	Anytime	Low
Water quality	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Rehabilitate dissolved oxygen in pools and weir-pools during periods of low flow	W1a	Mixing	No evidence of issues but could be low at times due to low flows.	Spring	Freshes
	W1b	Habitat maintenance	No evidence of issues but could be low at times due to low flows.	Summer	Low
Rehabilitate total nitrogen concentrations	W2	Habitat maintenance	Total nitrogen concentrations have exceeded the SEPP objective since 1992.	Summer	Low
Rehabilitate electrical conductivity	W3a	Habitat maintenance	Electrical conductivity have exceeded the SEPP objective 10 out of the last 11 years.	Summer	Low
	W3b	Mixing	Electrical conductivity have exceeded the SEPP objective 10 out of the last 11 years.	Spring	Freshes

1.3.7 Flow recommendations

Flow recommendations have been provided for the flow components described below. A summary of the recommendations for Reach 3 is shown in Table 0-7.

Summer – Cease to flow

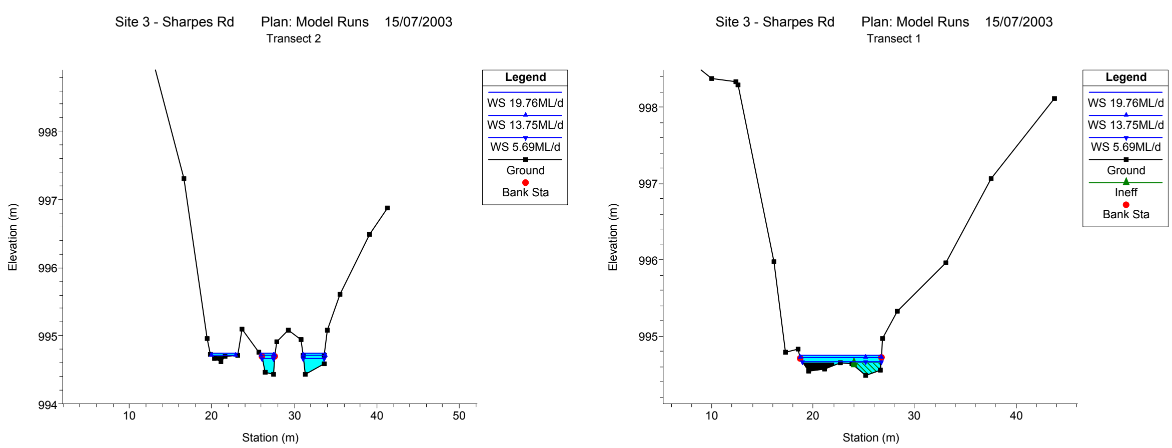
Cease to flow events are recommended to create disturbance that maintains the macroinvertebrate species diversity already present within this reach. Disturbance creates patches and a range of habitats that enable colonisation by a range of predatory and grazing macroinvertebrate species (Lake, 2003). The recommendation for a flow of 0 ML/d occurring once a year replicates the natural frequency and is deemed sufficient for resetting macroinvertebrate communities. A duration of ten days is long enough for biota in the riffles to be affected by water loss yet not too long so as to reduce habitat quality in the pools (Figure 0-33).



■ **Figure 0-33 Duration (left) and frequency (right) of summer spells below 1 ML/d under natural and current conditions in Reach 3.**

Summer – low flow

A low flow of 20 ML/d is recommended for Reach 3. Flows of this magnitude will maintain minimum habitat conditions for aquatic biota by inundating the bottom of the channel yet leave benches exposed for entrainment and weathering of organic matter (Figure 0-34). The HEC-RAS model indicates a flow of this magnitude would provide a maximum depth of 1.6 m in the pools at Transect 7 and 26 cm in the shallower areas. A maximum depth of 26 cm is considered enough to allow longitudinal fish movement and connectivity that will slow the deterioration of water quality in pools. Any flow magnitude less than 20 ML/d will not provide adequate flow area and velocity to allow fish movement between pools following cease to flow events.

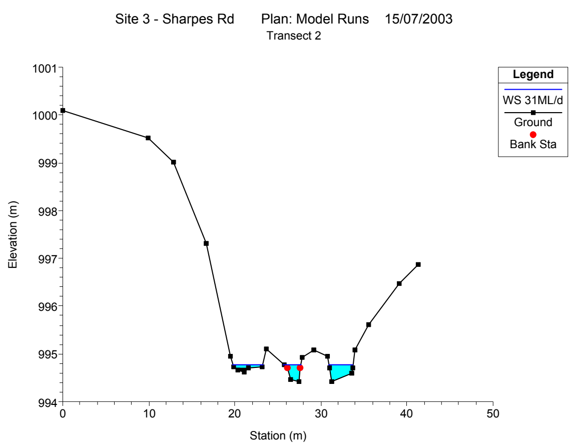


■ **Figure 0-34 Stage height at Transect 2 (left) and Transect 1 (right) for trialed summer low flows of 20, 14 and 6 ML/d at Reach 3.**

Summer – fresh

The recommended summer fresh flow of 31 ML/d is a critical cue for Australian Grayling to spawn during summer to early autumn and the upstream migration of Spotted Galaxias that are found downstream of She Oaks in the vicinity of Batesford. In addition, it will increase the depth in the channels inundated during low flow by a minimum of 3 cm and provide flow in the channels that were only wetted during low flows (Figure 0-35). This will enhance connectivity between pools, allowing fish movement in the deeper channels and refuge in the shallower channels as well as improving water quality by flushing and turning over pools.

A frequency of once per year may not be biological significant and more than one, preferably three freshes, are recommended to ensure a biological effect (Figure 0-36). Although only a short duration is required to scour excess silt from within riffles and flush nutrients from deep pools, a duration of ten days is recommended to ensure fish respond to the cue and have the opportunity to move.



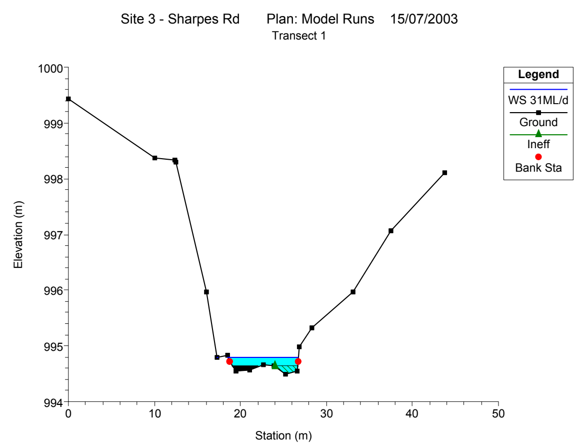
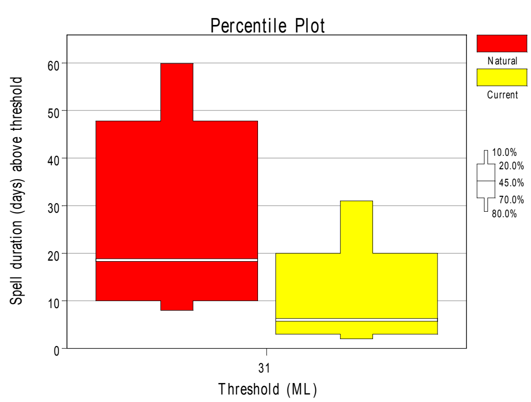


Figure 0-35 Stage height at Transect 2 (left) and Transect 1 (right) for recommended summer fresh threshold of 31 ML/d at Reach 3.



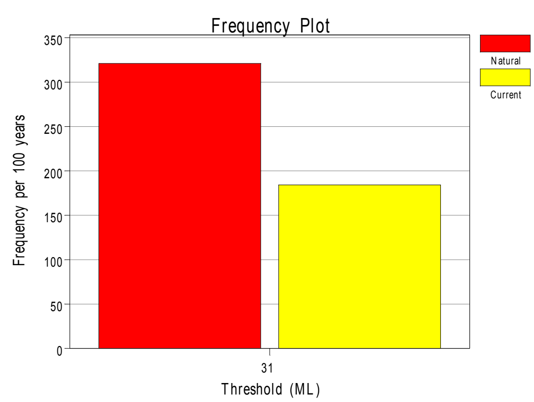
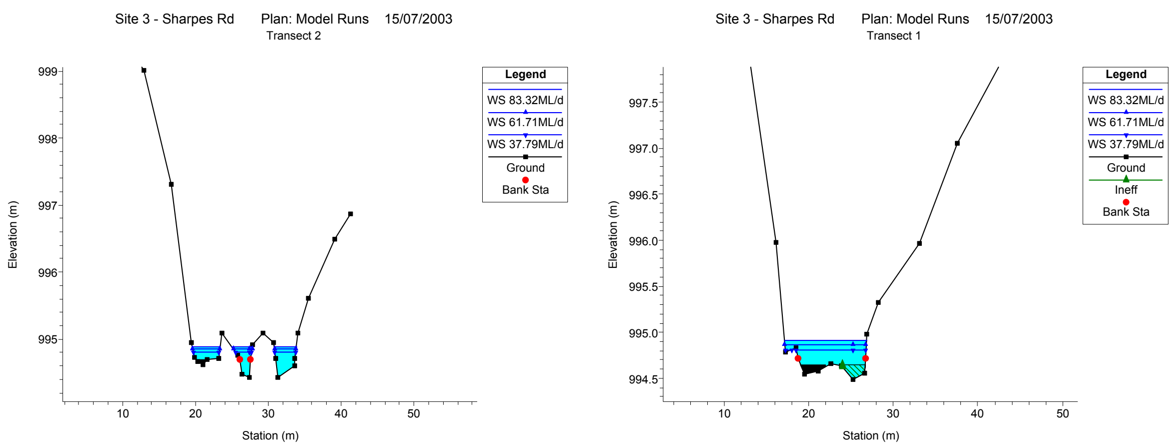


Figure 0-36 Duration (left) and frequency (right) of summer spells above 31 ML/d under natural and current conditions in Reach 3.

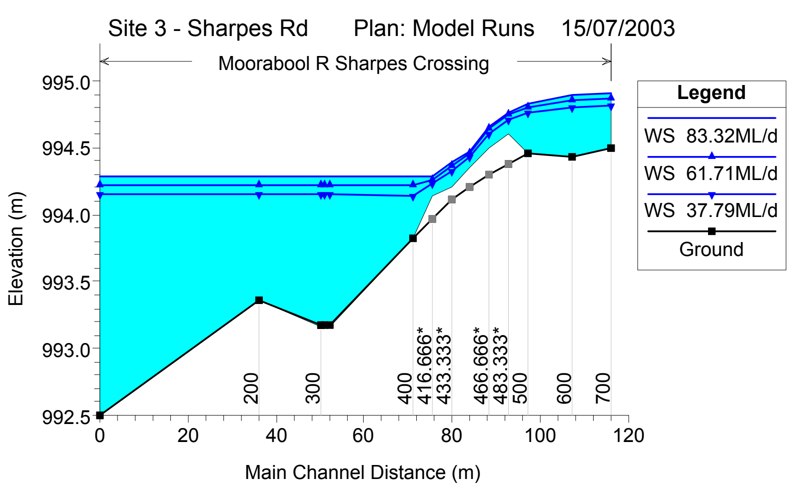
Winter – low

A winter low flow of 83 ML/d is recommended to provide a range of hydraulic habitats for native fish and macroinvertebrates. At this flow, high and low flow habitats will be connected as water depth will be maintained in the pools and all channels inundated either side of the vegetated bar at Transects 2 and 3 (Figure 0-37, Figure 0-38). This will provide excellent habitat for native fish particularly where large woody debris is inundated and the maintenance of riffle habitat for macroinvertebrates. Maximum water depth in the shallower channel areas is 37 cm and adequate for the movement of native fish species in this reach. Flows of this magnitude will also inundate most emergent and marginal aquatic vegetation zones established around the edge of the wetted channel and will suppress encroaching terrestrial vegetation that is sensitive to inundation.

Flows lower than 83 ML/d will not inundate the entire channel at most transects, therefore limiting the amount of habitat available to instream fauna.



■ **Figure 0-37 Stage height at Transect 2 (left) and Transect 1 (right) for trialed winter low flows of 38, 62 and 83 ML/d at Reach 3.**

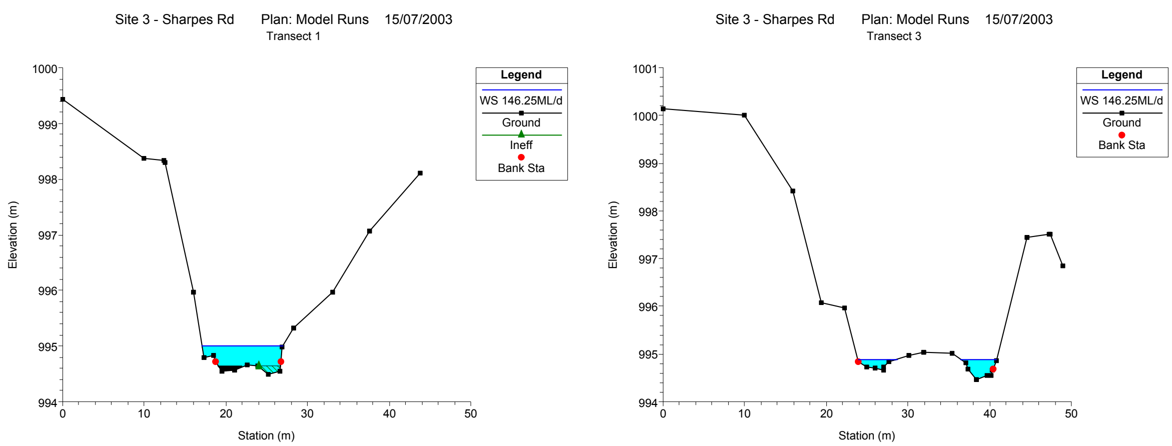


■ **Figure 0-38 Longitudinal profile for recommended winter low threshold of 83 ML/d at Reach 3.**

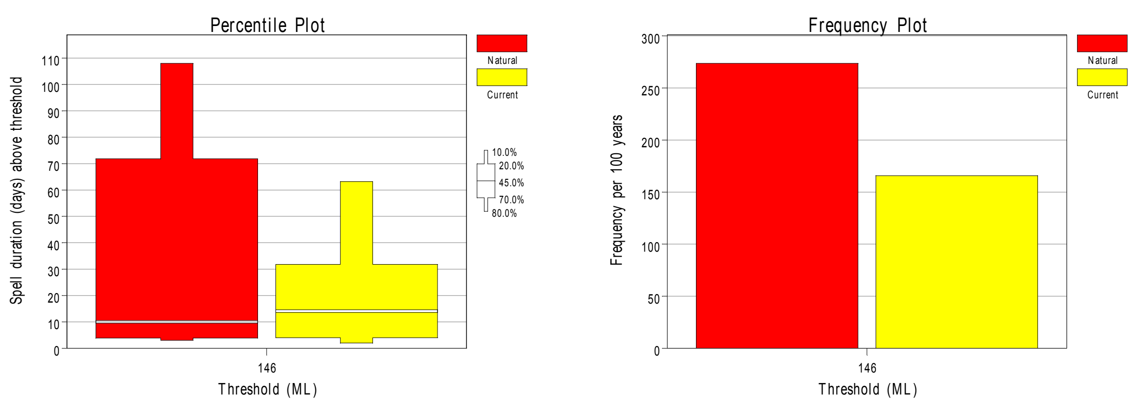
Winter – fresh

This reach is characterised by low level benches and a vegetated bar at Transect 2 and 3. A winter fresh flow of 146 ML/d will inundate the margins of these benches and assist in the reduction of cover of terrestrial exotic grasses favoured by low hydrological stability to native floodplain species such as rush (Figure 0-39). In addition, this flow will flush the litter present in the high flow left channel downstream, providing organic matter and therefore energy to sites further downstream.

The winter fresh should occur at a maximum of twice per year in order for the effects to be cumulative. A duration of five days is recommended on the basis that this is adequate timing for inundation of terrestrial exotic grasses and movement of organic litter downstream (Figure 0-40).



- **Figure 0-39 Stage height at Transect 1 (left) and Transect 3 (right) for recommended winter fresh threshold of 146 ML/d at Reach 3.**



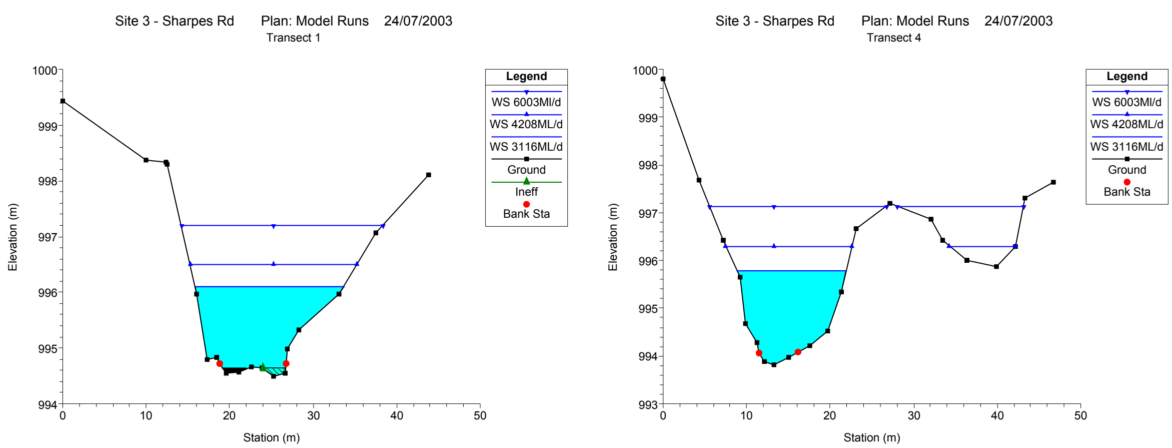
- **Figure 0-40 Duration (left) and frequency (right) of winter spells above 146 ML/d under natural and current conditions in Reach 3.**

Winter – high

Higher flows in winter are required to maintain the geomorphic processes of re-shaping the channel elements (scouring pools etc) and maintenance (ie. wetting) of riparian communities such as tea-tree. A flow of 3115 ML/d will ensure all channels are thoroughly inundated, and provide a cue for the downstream spawning migration of Tupong and gradual upstream migration by juveniles (Figure 0-41). A flow of this magnitude will not inundate the high flow channel at Transect 4 and is not required to achieve the desired ecological objectives.

The winter high flow of 3115 ML/d also corresponds to the annual return high flow (Figure 0-42). A higher frequency will not provide any extra biological benefits. A flow of this magnitude will achieve the desired ecological effects in one day and is 70% of the natural exceedence flow events. The recommended duration of one to two days is adequate time for sediment to be transported and Tupong to move downstream.

Over bank flows have not been recommended for this reach as there are no significant wetlands identified in the area and little floodplain value.



▪ **Figure 0-41 Stage height at Transect 2 (left) and Transect 4 (right) for trialled winter high flows of 3115, 4209 and 6003 ML/d at Reach 3.**

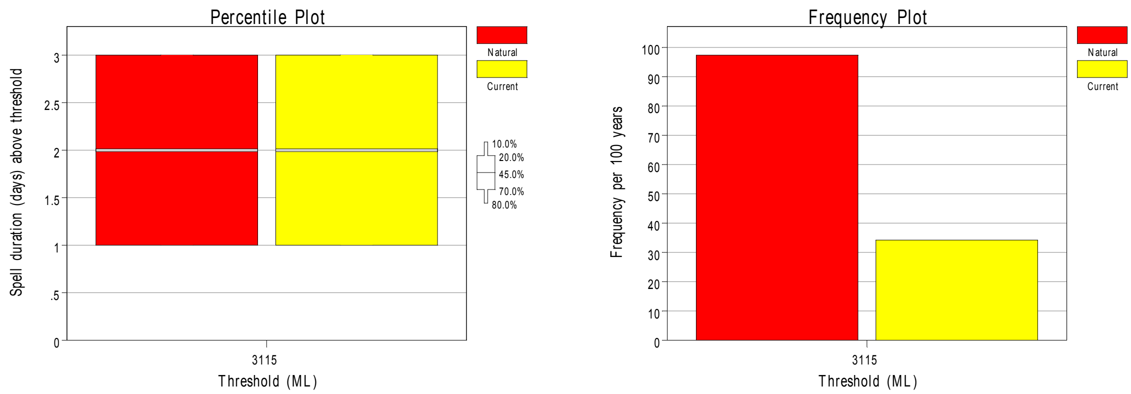


Figure 0-42 Duration (left) and frequency (right) of winter spells above 3115 ML/d under natural and current conditions in Reach 3.

Table 0-7 Flow recommendations for Reach 3.

River	Moorabool River			**Reach**	East Moorabool River below Lal Lal Reservoir to Sharp Road, She Oaks
Flow					**Rationale**
Season	**Flow component**	**Magnitude**	**Frequency**	**Duration**	**Objective**
Summer Dec - May	Cease to flow	0 ML/d	Annual	10 days	M1a, V2b
	Low flow	20 ML/d	Annual	Dec - May	F1a, F2a, F2a, F3a, F4a, F5a, F6a, F8, F9a, V2b, H2, W1a, W1b, W2, W3a
	Fresh	> 31 ML/d	Three a year	10 days	F1b, F4b, F5c, F9b, H1a, H1b
Winter Jun - Nov	Low flow	83 ML/d	Annual	Jun - Nov	F1a, F2a, F3a, F4a, F5a, F6a, F8, F9a, V2a, H2
	Fresh	> 146 ML/d	Two a year	5 days	M1b, V3, W1a, W1b, W3b
	High flow	> 3000* ML/d	One a year	1 - 2 days	F1c, F2b, F3b, F4c, F5b, F6a, F6c, F7b, F9c, V3, V4, H1a, H1b

* This value has been rounded to 3000 ML/d instead of 3115 ML/d for ease of reporting

1.4 Reach 4: Moorabool River below Sharp Road, She Oaks to the confluence with the Barwon River.

This reach is located downstream of Sharp Road, She Oaks Weir, to the confluence with the Barwon River at Fyansford (Figure 0-43).

The in-stream and riparian vegetation communities varied throughout the reach and ranged from poor to fair condition at the more populated lower end to excellent condition at the top end of the reach at the southern end of Steiglitz Historical Park.

▪ **Figure 0-43 Looking upstream from the confluence of the Barwon River (left) and Moorabool River (right) (March 2003).**

1.4.1 Site description

One survey site was located immediately downstream of Bakers Bridge Road. At this site, the river was a deeply incised u-shaped channel with a series of alternating deep pools and shallow glides (Figure 0-44, Figure 0-45). The channel is mostly controlled by bedrock in the deeper pools with interstitial fines and organic matter. In the shallower glides, the substrate consisted of cobbles, sand and fine organic matter.

Riparian vegetation consisted of very sparse mature River Red Gums along with occasional Blackwood on the bank face. Stock access was evident where pasture grasses were dominant or in some cases no grass, but bare earth.

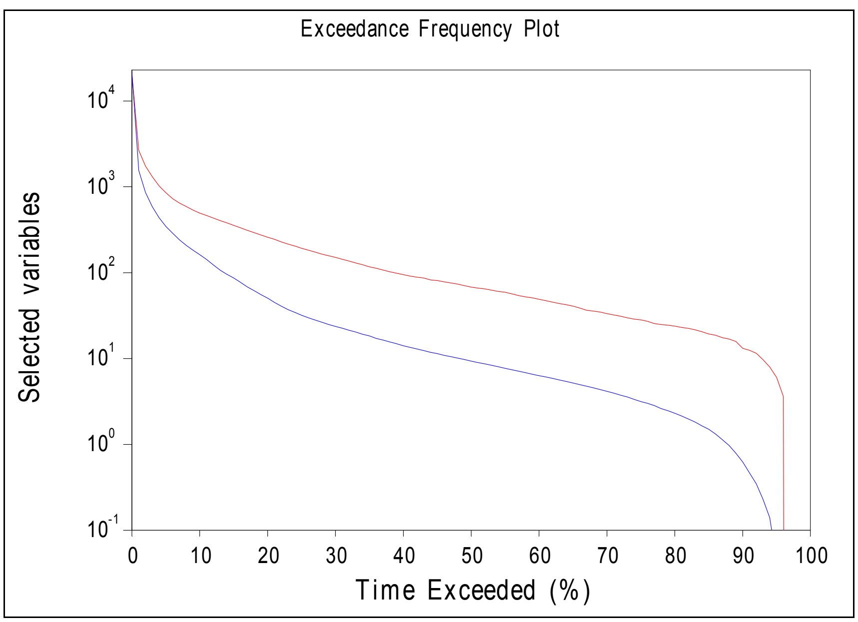
In-stream vegetation consisting of floating green Azolla was present in most pools, along with emergent species such as rush, Cumbungi, Common Reed, Water Ribbons (*Triglochin procerum*) and submerged species such as Ribbonweed, Elodea, Watermilfoil and spike rush (*Eleocharis spp*). A light loading of large woody debris was also present.

▪ **Figure 0-44 Moorabool River Bakers Bridge Road at Transect 1 cross section (May 2003).**

▪ **Figure 0-45 Moorabool River Bakers Bridge Road at Transect 5 cross section (May 2003)**

1.4.2 Hydrology

Figure 0-46 shows the impact from diverted flows at She Oaks Weir and large extractions by licensed diverters from a number of small weirs within this reach. Compared to natural, current cease to flow and median flows have decreased (from 68 ML/d to 10 ML/d) such as there is a loss in flow variability. Flows are now low and more constant.



▪ **Figure 0-46 Moorabool River below She Oaks at Sharp Road to below Batesford. Dashed red line – natural, solid blue line – current.**

1.4.3 Environmental values

Eight species of native fish have been previously recorded from the Moorabool River downstream of She Oaks Weir (Table 0-8). Surveys indicate that these species, except for the Short-finned Eel are restricted in distribution to the lower reaches downstream of Batesford.

One species, the Australian Grayling, is listed as vulnerable in Victoria, listed under the Victorian *FFG Act 1988*, listed as threatened under the Commonwealth *EPBC Act 1999* and listed on the 2002 IUCN Red List of Threatened Species.

- **Table 0-8 Fish species recorded in the Moorabool River below She Oaks weir (NRE, 2003a; Zampatti and Grgat, 2000).**

Scientific name	Common name	Victorian conservation status	Migratory	Last observed
Gadopsis marmoratus	River Blackfish	Common	N	1998
Galaxias maculatus	Common Galaxias	Common	Y	1998
Galaxias truttaceus	Spotted Galaxias	Common	Y	1998
Anguilla australis	Short-finned Eel	Common	Y	1998
Mordacia mordax	Short-headed Lamprey	Common	Y	1998
Prototrocetes maraena	Australian Grayling	Vulnerable	Y	1998
Nannoperca australis	Southern Pygmy Perch	Common	N	1998
Pseudaphritis urvillii	Tupong	Common	Y	1998

A total of 11 Victorian threatened water dependent bird species have been recorded within the Moorabool River catchment downstream of Moorabool Reservoir and Bostock Reservoir (NRE, 1999b) (**Error! Reference source not found.**). This list includes the critically endangered Little Egret and Intermediate Egret and the endangered Great Egret. Five species are listed under the *FFG Act 1998*. The Great Egret is also declared internationally significant by the Japan and Australia Migratory Bird (JAMBA) and China and Australian Migratory Bird (CAMBA) Agreements.

1.4.4 Water quality

Water quality monitoring is undertaken on the Moorabool River at Batesford (VWQMN site 232202). A summary of water quality data at this site and comparison to the draft SEPP objectives (EPA, 2001) and the ANZECC water quality guidelines (ANZECC, 2000) is provided in **Error! Reference source not found.**.

The draft SEPP objective for total nitrogen and electrical conductivity has been exceeded on nine occasions for which it was measured during the past eleven years. Total phosphorus concentrations were also high and did not comply with the draft SEPP objective of ≤ 0.04 mg/L for seven of the nine years statistics were able to be produced. Dissolved oxygen can be potentially low due to extended periods of low flow and has the potential to be lethal to native fish. However, the dissolved oxygen has met the ANZECC (2000) guideline since 1992.

Turbidity was quite variable and did not comply with the draft SEPP objective of ≤ 10 NTU during 1992-93, 1996 and 2000. pH complied with all draft SEPP objectives.

1.4.5 Issues

Prolonged periods of low flow, reduced median flow and lack of flow variability have been identified as the primary issues impacting environmental values present within this reach. This is the result of diversions at She Oaks, large extractions by licensed diverters and a number of small weirs impeding flow. Flow variability is crucial in maintaining populations of native fish species and improving habitat diversity.

However, it is likely that the prolonged low flow is this reach is the crucial factor for sustaining the high value fish communities and good riparian and instream conditions (such as habitat for River Blackfish and populations of Australian Grayling). In addition, increased flow may provide greater movement to native species such as River Blackfish but will also provide greater passage through the catchment to exotic species such as Carp. Australian Grayling are found within this reach and as such the flows should be managed for this vulnerable species.

Downstream of She Oaks, a number of weirs have been constructed over the past 50 years (Figure 0-47). The weirs create pools upstream allowing licensed diverters to extract water. Behind the weirs, organic matter and silt accumulate smothering aquatic vegetation and reducing habitat availability. Higher and more regular flushing flows should alleviate this problem over time.

- **Figure 0-47 Looking downstream at weir from bridge on the Midland Highway (March 2003).**

1.4.6 Ecological objectives

Based on the information obtained from the background review and the field inspection, ecological objectives have been developed for Reach 4 (Table 0-9).

Table 0-9 Ecological objectives for Reach 4.

Fish	No.	Process	Rationale	Timing of flow component	Relevant flow component
Maintain self-sustaining population of Australian Grayling	F1a	Habitat	Provide adequate habitat all year.	All year	Low
	F1b	Recruitment	Spawning possibly occurs when water levels rise (possibly mature adults migrate back upstream from sea to spawn). Spawn in same portion of river they inhabit	Spring/Summer	Freshes
	F1c	Movement	Upstream migration from sea at end of first year	Spring/Summer	High flows
Maintain self-sustaining population of Short-finned Eel	F2a	Habitat	Provide adequate habitat all year	All year	Low
	F2b	Movement	Upstream migration as elvers (also to overcome weirs)	Spring/Summer	High flows
Maintain self-sustaining population of Common Galaxias	F3a	Habitat	Provide adequate habitat all year	All year	Low
	F3b	Recruitment/Movement	Juveniles migrate upstream from sea.	Spring/Summer	High
Maintain self-sustaining population of Spotted Galaxias	F4a	Habitat	Provide adequate habitat all year	All year	Low
	F4b	Recruitment	Juveniles migrate upstream from sea	Spring/Summer	High/Freshes
	F4c	Movement	Post-spawning move back upstream	Spring/Summer	High
Maintain self-sustaining population of Short-headed Lamprey	F5a	Habitat	Provide adequate habitat all year	All year	Low
	F5b	Recruitment	Downstream migration to sea (related to marked increases in freshwater discharge)	Autumn/Spring	Freshes/High flow
	F5c	Breeding	Upstream spawning migration (reduced river flow and increased water temperature).	Spring/Summer	High
Maintain self-sustaining population of Tupong	F6a	Habitat	Provide adequate habitat all year.	All year	Low
	F6b	Recruitment	Downstream spawning migration	Autumn/Winter	High
	F6c	Movement	Gradual upstream migration by juveniles	Winter	High
Maintain self-sustaining population of River Blackfish	F7a	Habitat	Provide adequate habitat all year	All year	Low
	F7b	Movement	No apparent migration. Movement is generally limited to a home range 25 to 30 m, no	Spring/Summer	High

Fish	No.	Process	Rationale	Timing of flow component	Relevant flow component
			spawning migration		
Maintain self-sustaining population of Southern Pygmy Perch	F8	Habitat	Provide adequate habitat all year	All year	Low
Macroinvertebrates	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Maintain diverse macroinvertebrate community consisting of both slow water (Coenagrionidae) and fast water (Hydropsychidae) species.	M1a	Disturbance	Reset macroinvertebrate community – colonisation by new species	Summer	Freshes
	M1b	Habitat maintenance	Restore riffles	Winter/Spring	Freshes
	M1c	Habitat availability	Maintain riffles	Spring/Summer	Low
Vegetation	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Maintain in-stream macrophyte species diversity	V2a	Colonisation	Colonisation	Spring	Low
	V2b	Disturbance	Maintain instream species diversity	Summer	Low
Limit encroachment of in-stream vegetation and species common to non-flowing waterbodies such as Elodea and Azolla.	V3	Disturbance	In-stream vegetation in the lower Moorabool can be dominated by species common to non-flowing water bodies (weir pools create stagnant flow).	Winter/Spring	Freshes/High
Maintenance of riparian vegetation communities (eg. Silver Wattle and Blackwood).	V4	Wetting	Establishment and growth of riparian species	Winter	High
Maintain floodplain communities	V5	Inundation	Establishment and growth of floodplain species	Spring	High
Habitat/Processes	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Re-shape in-channel forms to maintain physical habitat diversity and complexity	H1	Transport of sediment	Flush sediment from behind weirs and maintain pool habitat	Winter	High
Maintain physical processes	H2	Organic matter transport	Flush organic matter through system that has accumulated in pools and perhaps behind weirs	Spring	High
Maintain woody debris/snag habitat	H3	Submergence	Bugs and fish (River Blackfish)	Anytime	Low

Water quality	No.	Process	Rationale	Timing of flow component	Relevant flow component
Rehabilitate dissolved oxygen in pools and weir-pools during periods of low flow	W1a	Mixing	No evidence of issues but could be low at times due to low flows.	Spring	Freshes
	W1b	Habitat maintenance	No evidence of issues but could be low at times due to low flows.	Summer	Low
Rehabilitate total nitrogen concentrations	W2	Habitat maintenance	Total nitrogen concentrations have exceeded the SEPP objective since 1992.	Summer	Low
Rehabilitate electrical conductivity	W3a	Habitat maintenance	Electrical conductivity have exceeded the SEPP objective 10 out of the last 11 years.	Summer	Low
	W3b	Mixing	Electrical conductivity have exceeded the SEPP objective 10 out of the last 11 years.	Spring	Freshes
Floodplains	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Restore floodplain communities	FLa	Wetting	River Red Gum regeneration	Spring	High
Restore floodplain processes (connectivity)	FLb	Inundation	Floodplain areas have been identified in the lower reaches, in the vicinity of Lethbridge.	Spring	High

1.4.7 Flow recommendations

Flow recommendations have been provided for the flow components described below. A summary of the recommendations for Reach 4 is shown in Table 0-10.

Summer –cease to flow

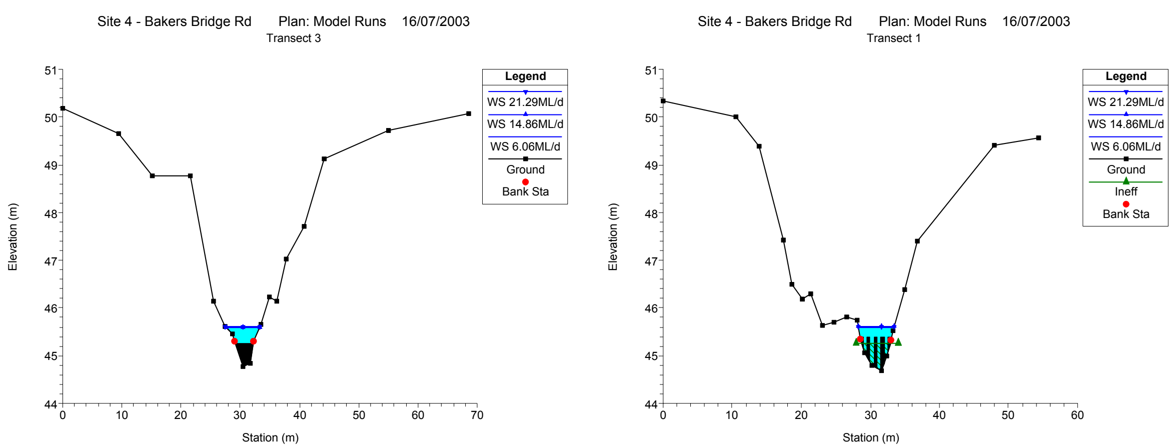
No cease to flow recommendation has been made for this reach because natural cease to flow periods were infrequent and short-lived (Figure 0-46). Cease to flow periods are unlikely to provide any real benefits and may pose a significant risk to remaining environmental values.

Summer – low

A low flow of 21 ML/d is recommended for Reach 4. A flow of this magnitude maintains minimum habitat conditions for aquatic biota by inundating the bottom of the channel and allowing adequate flow for fish movement between the shallow glides and deeper pools. HEC-RAS outputs of 6, 15 and 21 ML/d revealed little difference in depth at each of the sites, probably as a result of channel confinement (Figure 0-48, Figure 0-49). The depth at the shallowest point within the site at Transect 3 was 32 cm for 6 ML/d compared to 35 cm for 21 ML/d. Both of these depths will provide longitudinal connectivity throughout the reach.

However, these outputs also indicate that flows less than 21 ML/d will not provide adequate velocity in the glides. Velocity at each of the cross sections, for each of the modelled flows, showed a maximum three-fold increase between 6 ML/d and 21 ML/d. This is particularly important at Transect 3 where the minimum velocity was 0.06 cm/s and maximum 0.18 cm/s. A larger velocity is preferable to ensure flow through vegetation in the shallower areas and rehabilitation of dissolved oxygen in the pools.

▪ **Figure 0-48 Bakers Bridge Transect 1 looking downstream (May 2003).**

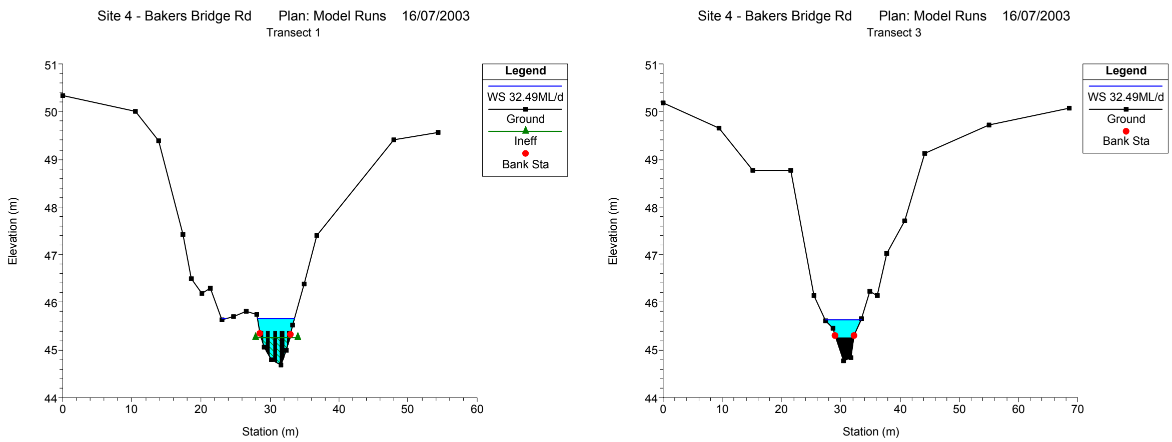


▪ **Figure 0-49 Stage height at Transect 3 (left) and Transect 1 (right) for trailed summer low flows of 6, 15 and 21 ML/d.**

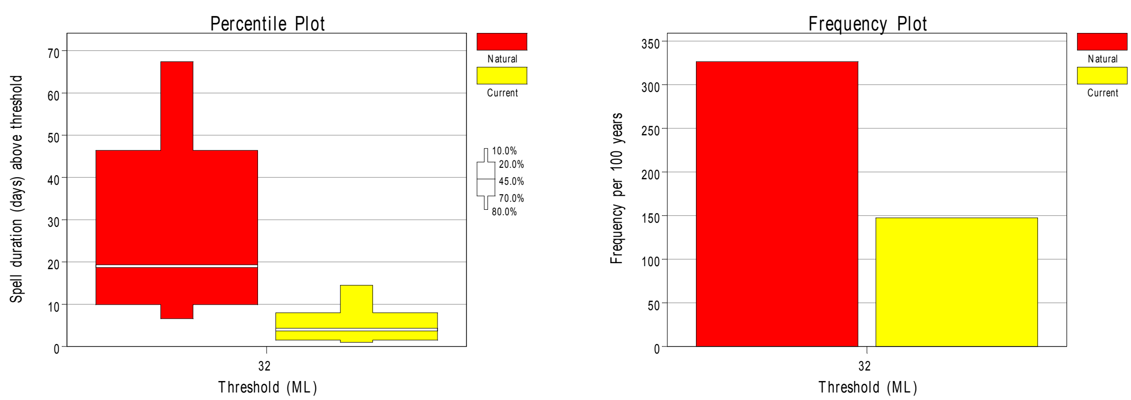
Summer – fresh

Freshes during the summer months, December to May, are important flow components for this reach. The recommended summer fresh flow of 32 ML/d is a critical cue for Australian Grayling, which require a rise in water level from May to July when larvae are washed to sea and another regular rise from February to April as a spawning trigger. In addition, these flows will provide greater wetted habitat area in the channels and increase depth in the glides by 3 cm (Figure 0-50). This will enhance connectivity between the shallower glides and deeper pools.

Summer freshes of 32 ML/d would occur naturally about three times per year. Currently they occur less than twice a year (Figure 0-51). A fresh occurring once per year may not be biologically significant and more than one fresh, preferably three are required to ensure that the cue has its effect. A duration of ten days is recommended to ensure Australian Grayling receive the cue for movement and actually have time to move, as well as disperse low flow favoured vegetation species such as Azolla and provide flushing and mixing within the deeper pools. The natural flow duration of ten days is the 70% exceedence flow of natural events.



■ **Figure 0-50 Stage height at Transect 1 (left) and Transect 3 (right) for recommended summer fresh threshold of 32 ML/d at Reach 4.**



■ **Figure 0-51 Duration (left) and frequency (right) of summer spells above 32 ML/d under natural and current conditions in Reach 4.**

Winter – low

The winter low flow of 86 ML/d is recommended to provide a sustained link between the glide and pools habitats throughout the reach (Figure 0-52). As such, an increase in the wetted area of the channel and a range of hydraulic habitats will be provided. At Transect 1 for example, the left bank channel will be wetted therefore providing a refuge for native fish (Figure 0-53, Figure

0-54). In addition, sustained flow will suppress encroaching terrestrial vegetation that has been able to colonise the shallow glides during summer flows.

Flows lower than 86 ML/d will not provide a link between all habitats in the reach and in particular wet the high flow channel at Transect 1 (Figure 0-53).

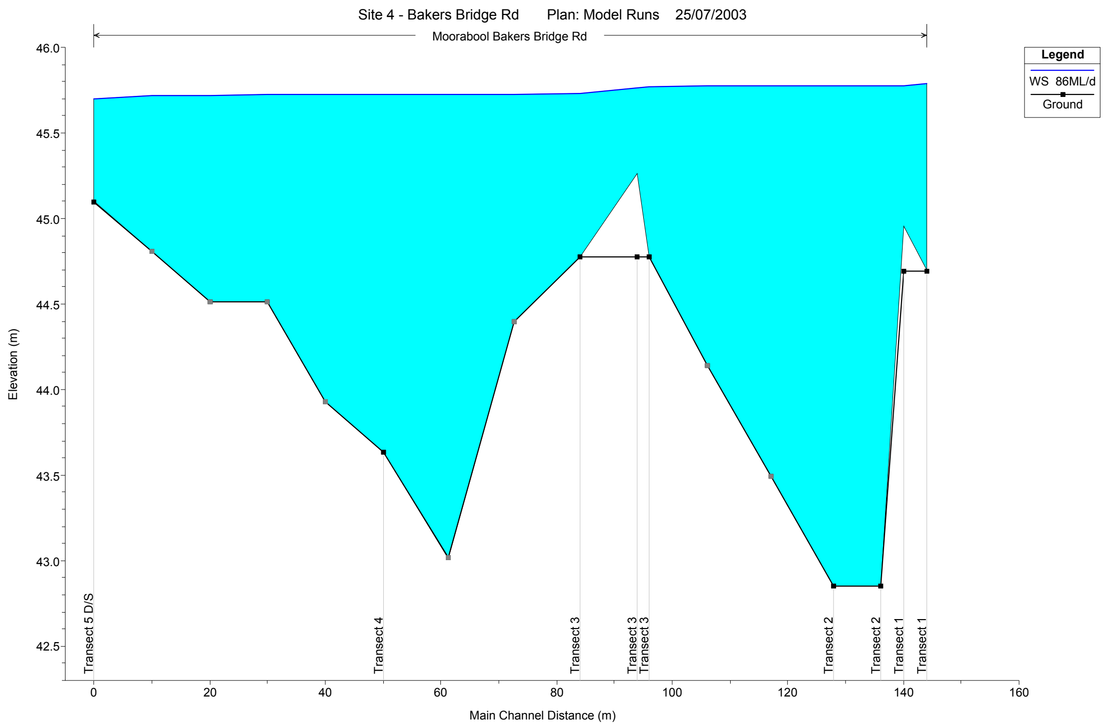
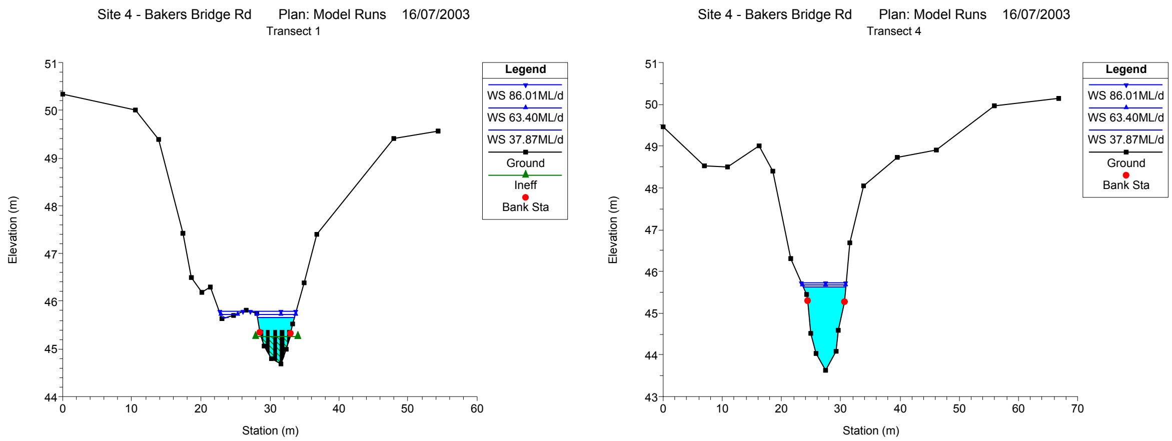


Figure 0-52 Longitudinal profile for recommended winter low threshold of 86 ML/d at Reach 4.

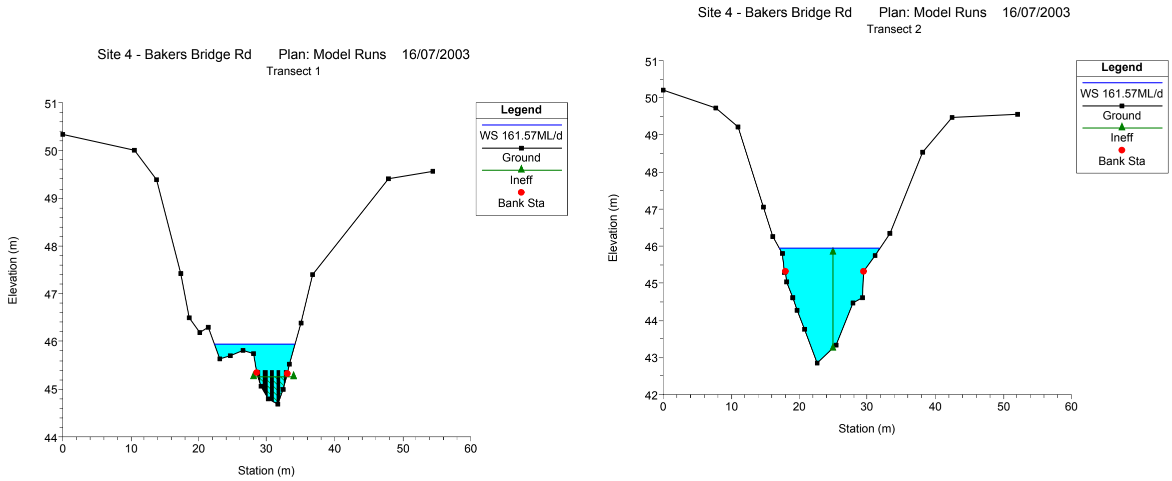


▪ **Figure 0-53 Stage height at Transect 1 (left) and Transect 4 (right) for modelled winter low flows of 86, 6. and 38 ML/d at Reach 4.**

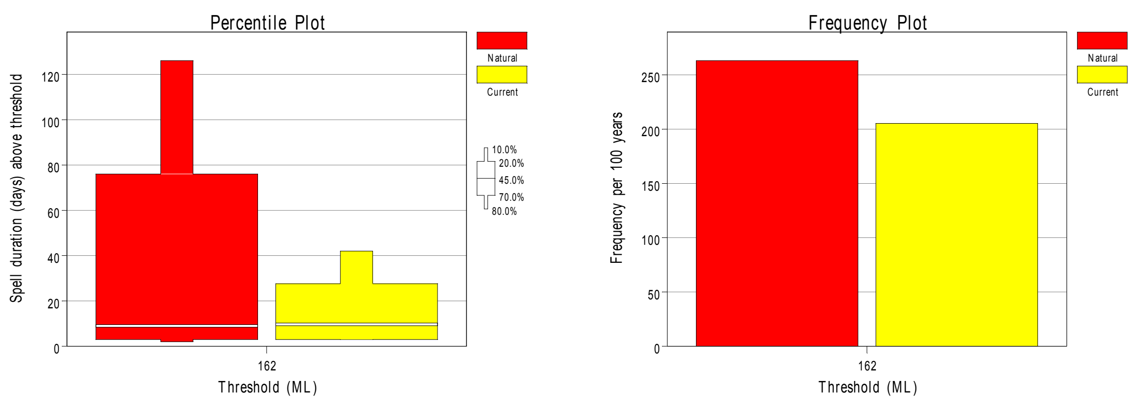
▪ **Figure 0-54 Bakers Bridge Road at Transect 1 looking downstream (May 2003).**

Winter – fresh

The recommended winter fresh flow of 162 ML/d is critical in assisting the downstream migration of Short-headed Lamprey to sea and providing further movement to other species such as River Blackfish. In addition, it will inundate the higher benches and link the high and low flow channel and Transect 1 (Figure 0-55). This will ensure organic material present on the benches is swept into the river, providing an important source of carbon substrate and energy downstream. It is recommended that a winter fresh should occur three times per year during this period in order to provide adequate opportunity for fish movement over weirs and more closely replicate the natural conditions (Figure 0-56). The duration is recommended to be a minimum of ten days in order to provide a sufficient timing for fish movement during each event.



■ **Figure 0-55 Stage height at Transect 1 (left) and Transect 2 (right) for winter fresh flow threshold of 162 ML/d at Reach 4.**



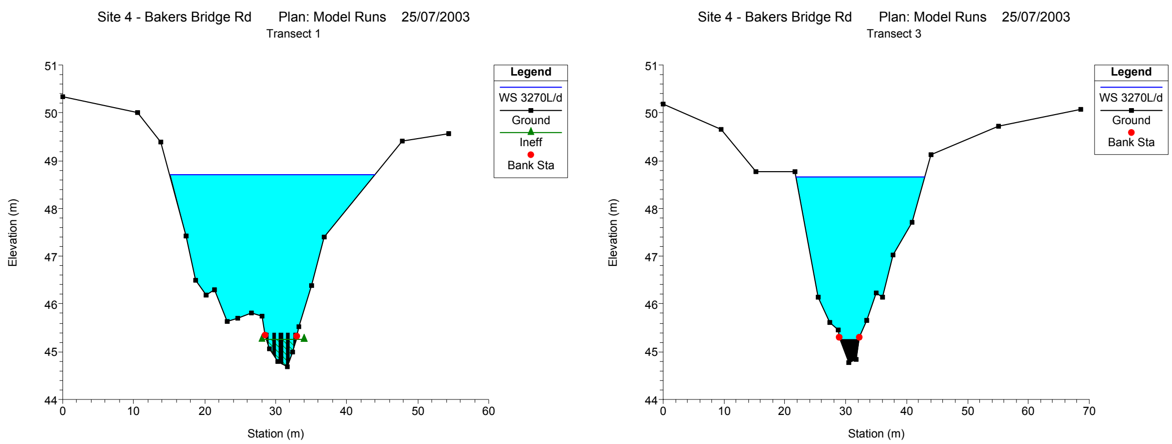
■ **Figure 0-56 Duration (left) and frequency (right) of winter spells above 162 ML/d under natural and current conditions in Reach 4.**

Winter – high

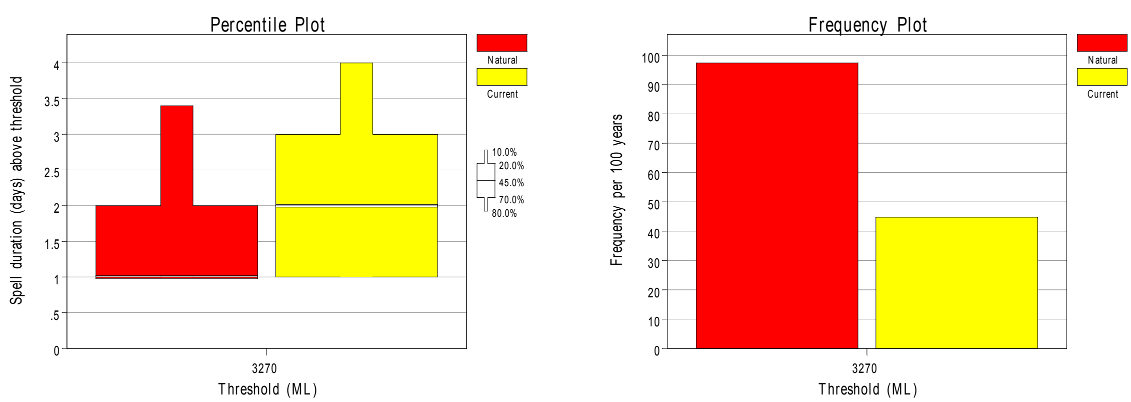
Winter high flows are recommended to provide geomorphic disturbance and inundation of River Red Gums and floodplains identified further downstream in the vicinity of Lethbridge. In addition, juvenile Australian Grayling also require high flows for adult movement between October to December and larvae which are washed to sea between May and July.

A flow of 3270 ML/d will almost fill the channel, inundating all benches and riparian communities as well as transporting sediment downstream (Figure 0-57). A flow of this magnitude will also remove sediment and organic matter accumulated behind the weirs and provides increased inputs to the Barwon River and associated lakes.

Under natural conditions flows of this magnitude occurred once a year, however under current conditions this frequency occurred once every two years (Figure 0-58). An annual event is recommended, as a frequency greater than this for a magnitude of this size is not required ecologically and would in fact create excessive disturbance to aquatic biota. The recommended duration of one to two days is adequate time for sediment to be transported and Australian Grayling to move downstream.



■ **Figure 0-57 Stage height at Transect 1 (left) and Transect 3 (right) for winter high flow threshold of 3270 ML/d at Reach 4.**



■ **Figure 0-58 Duration (left) and frequency (right) of winter spells above 3270 ML/d under current and natural conditions in Reach 4.**

- **Table 0-10 Flow recommendations for Reach 4.**

River	Moorabool River			Reach	Moorabool River below Sharp Road, She Oaks to confluence with the Barwon River
Flow					**Rationale**
Season	**Flow component**	**Magnitude**	**Frequency**	**Duration**	**Objective**
Summer Dec - May	Cease to flow	NR			
	Low flow	21 ML/d	Annual	Dec - May	F1a, F2a, F4a, F5a, F6a, F7a, F8, M1c, V2a, V2b, H3, W2, W3a
	Fresh	> 32 ML/d	Minimum 3 per year	10 days	F1b, F3a, F3b, F4b, M1a, W1a, W3b
Winter Jun - Nov	Low flow	86 ML/d	Annual	Jun - Nov	F2a, F3a, F4a, F5a, F6a, F7a, F8, H3
	Fresh	> 162 ML/d	Minimum 3 per year	10 days	F1b, F4b, M1b, W1a
	High flow	> 3000* ML/d	One year	1 – 2 days	F1c, F2b, F4b, F4c, F5b, F5c, F6b, F6c, F7b, V3, V4, V5, H1, H2, Fla, Flb

NR – No flow recommendation provided
* This value has been rounded to 3000 ML/d instead of 3270 ML/d for ease of reporting

1.5 Ramp rates

The rate at which flows rise and fall are known as ramp rates. These rates are environmentally significant particularly for short duration spells such as freshes and bank-full flows. If rates of rise are too fast they may exceed the ability of biota to adapt, thereby causing stress. Rapid falls in flow can increase the risk of bank failure leading to increased erosion and sediment loads.

Median ramp rates were calculated from daily flow data recorded at flow gauges downstream of all storages on the Moorabool River. Due to the large scatter in the data a single intermediary ramp rate is for all reaches. Median ramp rates are recommended because they provide the most conservative estimate of maximum rates of rise and fall in the Moorabool River.

The ramp rate recommendations are provided as a factor of the previous days flow. For example a recommended rate of rise of 1.6 stipulates that flow on a given day should not exceed 1.6 times the previous day’s flow.

The recommended ramp rates should be applied to any change in flow, including changes from high to low flow seasons, freshes and high flows. The recommended ramp rates are:

- Rise – 1.3
- Fall – 0.8